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...ENSBY'S MANUAL
FOR THE
...L. MARINE BOARDS.

[illegible]

A MANUAL

FOR THE USE OF

CANDIDATES REQUIRING A CERTIFICATE OF COMPETENCY

AS

MATES AND ORDINARY MASTERS;

AND COMPRISING

I. The Principles fully laid down and Taught by Examples.
II. Two Methods of Finding the Time of High Water, being those required by the Local Marine Boards of England and Scotland.
III. Questions in Astronomy, with Answers.

BY

EDWARD J. HENESSEY,

MASTER OF THE BOARD OF TRADE SCHOOL OF NAVIGATION, ABERDEEN;
LATE OF THE NAVIGATION SCHOOLS, LONDON AND LIVERPOOL.

WITH NINE ILLUSTRATIONS.

ABERDEEN: LESLIE & MAULE.
EDINBURGH: JOHN MENZIES. LONDON: SIMPKIN, MARSHALL, & CO.
LIVERPOOL: GEO. PHILIP. GLASGOW: HUTCHESON CAMPBELL.
PETERHEAD: W. L. TAYLOR.

MDCCCLIX.

187. a. 36.

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PREFACE.

THAT the majority of Seamen do not pursue their studies when absent from our Schools is a fact too well known for me to enlarge upon. I am aware, however, that they are not wholly to blame, seeing they are compelled to follow a science of whose alphabet the majority of seamen are totally ignorant. If the Board of Trade, with whom the matter specially rests, wishes the British Seaman to acquire a taste for Nautical Science, it must organise a system very different from that now in force, before the success desired can be attained. Having long felt the want of a work compendious and yet sufficiently simple, the following Manual has been compiled, with the view of its being useful as a Text-Book for Mariners while in school, and more particularly to enable them to follow up with advantage at sea the instructions they may have received while in port.

In working out the problems in the book, it may be thought I have been somewhat verbose, and to have given more explanations than were deemed necessary; but I have chosen rather to err in that direction, knowing by experience the difficulties to be sustained, consequent on the want of a proper elementary education on the part of those, who from time to time present themselves for examination. I trust that the class of seamen for whom this Manual is designed will find it serviceable, and that by its use they will be enabled to prosecute their studies, particularly while at sea, and be less dependent on the assistance of a teacher.

Norie's Tables have been used in preference to others, that work being most in repute with seamen. I must say, however, that, in my opinion, a great fault with Norie is redundancy of Tables. This has the effect of rendering Seamen careless and inaccurate, trusting too implicitly to extraneous assistance, and so defeating the object the Board of Trade has in view, viz. that they shall be able to compute for themselves.

E. J. H.

Board of Trade Navigation School.
Aberdeen, 1st *January* 1859.

NOTICE

OF

EXAMINATIONS OF MASTERS AND MATES,

Established in Pursuance of the MERCANTILE MARINE ACT, 1850;

AND OF

VOLUNTARY EXAMINATIONS IN STEAM.

To come into operation on the 1st September 1852.

NO Foreign-going* vessel is permitted to clear out from any custom-house in the United Kingdom unless the masters and mates respectively are in possession of Certificates, either of Service or of Competency.

The Certificate of Service entitles an officer, who has already served as either master or mate in the British merchant service before the 1st January 1851, to go in those capacities again, and may be had by application to the Registrar-General of Seamen, Custom-House, London, on the transmission of the necessary certificates and testimonials.

Certificates of Competency will be granted by the Board of Trade to all mates and masters who have passed examinations, whether under the old or the present regulations, and also to all officers who have passed Lieutenants', Masters', and Second Masters' examinations in the Royal Navy and East India Company's Service, unless special reasons to the contrary exist; and any person desirous of exchanging a passing certificate—obtained under the former Board of Examiners—for a Certificate of Competency, should send it to the Registrar-General, as before mentioned, with a request to that effect, and state the port to which he wishes it to be sent, where it will be delivered to him by the Collector of Customs or the Shipping Master.

All other officers, entering for the first time upon their duties, whether as mate or master, will be required to undergo an examination before one of the Local Marine Boards before they can act in either of those capacities.

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* By a Foreign-going vessel is meant one which is bound to some place out of the United Kingdom, beyond the limits included between the River Elbe and Brest.

For this purpose, Examiners have been appointed under the Local Marine Boards, and arrangements have been made for holding the examinations at the under-mentioned ports upon the day specified against them; and these days are so arranged for general convenience, that a candidate wishing to proceed to sea, and missing the day at his own port, may proceed to another port where an examination is coming forward. The days for commencing the examinations at the various ports are as follow:—

PLACES.	DAYS.
ABERDEEN* ...	Fridays and Saturdays in the first and third week in each month.
BELFAST	1st and 3d Tuesday in each month.
BRISTOL*	1st Friday and 3d Tuesday in each month.
CORK	4th Monday in each month.
DUBLIN	1st and 3d Thursday in each month.
DUNDEE*	Saturday in each week.
GLASGOW* .... GREENOCK* ...	Thursdays, held alternately at each place.
HULL*	2d Tuesday in each month.
LEITH*	2d Tuesday and 3d Saturday in each month.
LIVERPOOL*	Monday, Tuesday, Thursday, and Friday in each week.
LONDON*	Monday for examining Testimonials; Tuesday, Wednesday, Thursday, Friday, and Saturday for examination.
NEWCASTLE ..	1st day of each month, not being Sunday.
SHIELDS*	10th day of each month, ditto.
SUNDERLAND* ...	20th day of each month, ditto.
PLYMOUTH*	3d Wednesday in each month.

The examinations required for qualification for the several ranks undermentioned, are as follow:—

A SECOND MATE must be 17 years of age, and must have been 4 years at sea.

IN NAVIGATION.—He must write a legible hand, and understand the four first rules of arithmetic and the use of logarithms. He must be able to correct the courses steered for variation and leeway, and find the difference of latitude and longitude therefrom; be able to correct the sun's declination for longitude, and find his latitude by meridian altitude of the sun; and work such other easy problems of a like nature as may be put to him. He must understand the use of the sextant, and be able to observe with it, and read off the arc.

IN SEAMANSHIP.—He must give satisfactory answers as to the rigging and unrigging of ships, stowing of holds, &c.; must understand the measurement of the log-line, glass, and headline; be conversant with the rule of the road, as regards both steamers and sailing-vessels, and the lights carried by them.

---

* At these places extra Examinations are held.

An ONLY MATE must be 19 years of age, and have been 5 years at sea.

IN NAVIGATION.—In addition to the qualification required for a Second Mate, an Only Mate must be able to work a day's work complete, including the bearings and distance of the port he is bound to by Mercator's method. He must be able to observe and calculate the amplitude of the sun, and deduce the variation of the compass therefrom. He must know how to lay off the place of the ship on the chart, both by bearings of known objects, and by latitude and longitude. He must be able to use a sextant, and determine its error, and adjust it, and find the time of high water from the known time at full and change. He must also be able to find the longitude by chronometer from an observation of the sun.

IN SEAMANSHIP.—In addition to what is required by a Second Mate, he must know how to moor and unmoor, and to keep a clean anchor; to carry out an anchor; to stow a hold; and to make the requisite entries in the ship's log.

A FIRST MATE must be nineteen years of age, and have served five years at sea, of which one year must have been as either Second or only Mate, or as both.*

IN NAVIGATION.—In addition to the qualification required for an Only Mate, he must be able to observe azimuths and compute the variation; to compare chronometers and keep their rates; to work the latitude by single altitude of the sun off the meridian; and be able to use and adjust the sextant by the sun.

IN SEAMANSHIP.—In addition to the qualification required for an Only Mate, a more extensive knowledge of seamanship will be required, as to shifting large spars and sails, managing a ship in stormy weather, taking in and making sail, shifting yards and masts, &c., and getting cargo in and out; and especially heavy spars and weights, anchors, &c.; casting ship on a lee-shore; and securing the masts in the event of accident to the bowsprit.

A MASTER must be twenty-one years of age, and have been six years at sea, of which one year must have been as first or Only Mate, and one year as Second Mate; or two years as First and Only Mate.*

---

* Service in a superior capacity is in all cases to be equivalent to service in an inferior capacity.

In addition to the qualification for a First Mate, he must be able to find the latitude by a star, &c. He will be inquired of as to the nature of the attraction of the ship's iron upon the compass, and as to the method of determining it. He must possess a sufficient knowledge of what he is required to do by law, as to entry and discharge, and the management of his crew; as to penalties and entries to be made in the official log. He will be questioned as to his knowledge of invoices, charter-party, Lloyd's agent, and as to the nature of bottomry, and he must be acquainted with the leading lights of the channel he has been accustomed to navigate, or which he is going to use.

In cases where an applicant for a certificate as master ordinary has only served in a fore and aft rigged vessel, and is ignorant of the management of a square rigged vessel, he may obtain a certificate on which the words "*fore and aft rigged vessel*" will be written. This is not, however, to apply to Mates, who, being younger men, are expected for the future to learn their business completely.

An EXTRA MASTER'S EXAMINATION is intended for such persons as are desirous of obtaining command of ships and steamers of the *first class.* Before being examined for an Extra Master's Certificate an applicant must have served one year as a Master with *an ordinary Certificate of Competency,* or as a Master having a *First Class Certificate* granted by one of the former Boards of Examiners.

IN NAVIGATION.—As such vessels frequently make long voyages, to the East Indies, and the Pacific, &c., the candidates will be required, in addition to the qualification necessary for an ordinary Master, to work a lunar observation by both sun and star, to determine the latitude by the moon and star, by Polar star off the meridian, and also by double altitude of the sun, and to verify the result by Sumner's method. He must be able to calculate the altitudes of the sun or star when they cannot be observed, for the purposes of lunars, also to find the error of a watch by the method of equal altitudes. To correct the altitudes. observed with an artificial horizon.

He must understand how to observe and apply the deviation of the compass; and to deduce the set and rate of the current from the D. R. and observation. He will be required to explain the nature of great circle sailing, and know how to apply practically that knowledge; but he will not be required to go into the calculations. He must be acquainted with the law of storms, so far as to know how he may probably best escape those tempests common to the East and West Indies, and known as hurricanes.

In Seamanship.—The extra examination will consist of an inquiry into the competency of the party to heave a ship down, in case of accident befalling her abroad; to get lower masts and other heavy weights in and out; how to construct rafts, and as to his resources for the preservation of the ship's crew in the event of wreck, and in such operations of a like nature as the Examiner may consider necessary.

The candidates will be allowed to work out the various problems according to the method and tables they have been accustomed to use, and will be allowed five hours to perform the work; at the expiration of which, if they have not finished, they will be declared to have failed, unless the Local Marine Board see fit to extend the time.

Applicants for examination are required to give their names to the Shipping Master, or to the Local Marine Board at the place where they intend to be examined, on or before the day of examination, and to conform to the regulations in this respect which may be laid down by the Local Marine Board; and if this be not done, a delay will be occasioned.

The examinations will commence early in the forenoon on the days before mentioned, and be continued from day to day until all the candidates whose names appeared upon the Shipping Master's list on the day of examination are examined.

Testimonials of character, sobriety, and trustworthiness will be required of all applicants, and without which no person will be examined; and as testimonials will have to be forwarded to the office of the Registrar-General of Seamen in London for verification, before any certificates can be granted, it is desirable that candidates should lodge them as early as possible. Upon application to the Shipping Master, candidates will be supplied with a form, which they will be required to fill up and lodge with their testimonals in the hands of the Examiners.

The fee for examination must be paid to the Shipping Master. If a candidate fail in his examination, half the fee he has paid will be returned to him by the Shipping Master on his producing a document which will be given him by the Examiner.

The following are the fees to be paid by applicants for examination:—

	£	s.	d.
Second Mate	1	0	0
First and Only Mate, if previously possessing an inferior certificate	0	10	0
If not	1	0	0
Master, whether Extra or Ordinary	2	0	0

Home Trade Passenger Ships :—

	£	s.	d.
Mate	0	10	0
Master	1	0	0

Service as Mate in a Home Trade Passenger Ship is not allowed as such unless the person is possessed of an appropriate Certificate.

Any one who has been one year in possession of a Master's first-class Certificate granted by one of the former Boards of Examiners, or of an Ordinary Master's Certificate of Competency granted under the present Examiners, may pass an Extra Examination, and receive an Extra Certificate in exchange for his former one, without payment of any fee; but if he fails in his first examination he must pay half a Master's fee on his coming a second time; and the same sum for every subsequent attempt.

If the applicant passes, he will receive a document from the Examiner, which will entitle him to receive his Certificate of Competency from the Shipping-Master at the port to which he has directed it to be forwarded. If his testimonials have been sent to the Registrar to be verified, they will be returned with his certificate.

If an applicant is examined for a higher rank and fails, but passes an examination of a lower grade, he may receive a Cerficate accordingly, but no part of the fee will be returned.

As the examinations of Masters and Mates are made compulsory, the qualifications have been kept as low as possible; but it must be distinctly understood, that it is the intention of the Board of Trade to raise the standard from time to time, whenever, as will no doubt be the case, the general attainments of officers in the merchant service shall render it possible to do so without inconvenience; and officers are strongly urged to employ their leisure hours, when in port, in the acquirement of the knowledge necessary to enable them to pass their examinations; and Masters will do well to permit apprentices and junior officers to attend schools of instruction, and to afford them as much time for this purpose as possible.

EXAMINATIONS IN STEAM.

Arrangements having been made for giving to those Masters or applicants for Masters' Certificates who desire to do so, an opportunity of undergoing an examination as to their practical knowledge of the use and working of the steam-engine, these examinations will be conducted under the superintendence of the Local Marine Boards, at such times as they may appoint for the purpose; and the Examiners will be selected by the Board of Trade, from the engineer surveyors appointed under the Steam Navigation Act. The examination will not comprise intricate theoretical questions, but will be such as to satisfy the Examiner that the applicant is competent to control the working of the engine, and has such a knowledge of the ordinary parts of the machinery as will enable him to judge of the nature of an accident, and, in the absence of the engineer, to give the necessary directions in the engine-room. The practice will be as follows: The applicant must deliver to the Shipping Master a statement in writing to the effect that he wishes to be examined in Steam. If he is about to pass a Master's examination in navigation also, this statement must be on or annexed to the form E E; if he has a Master's Certificate of Competency, it must be delivered to the Shipping Master with his Certificate, so that due notice may be given to the Examiner, and so that the Board of Trade on receiving it may have the means of indorsing on his Certificate and recording the fact that he has passed in Steam. He must also, at the same time, pay a fee of £1, which will be applied in remunerating the Examiners. Notice will be given of the time at which the applicant is to attend to be examined; and if he passes, the result of the examination will be reported to the Board of Trade, and his Certificate of Competency will be issued or returned to him, as the case may be, with an indorsement as above mentioned, shewing that he has passed in Steam. If he fails, no notice of the failure will be recorded on the Certificate, but no part of the fee will be returned.

F. W. Beechey.
W. H. Walker.

T. H. Farrer,
Secretary.

Naval Department, Board of Trade,
May 1852.

DAY'S WORK.

Remarks.—(1.) In correcting the Courses for Variation and Leeway, the student must suppose himself standing at the centre of the Compass, and facing the ship's course.

(2.) *r* is written for right; *l* for left; *r n* right of north; *r s* right of south.

(3.) Westerly Variation is allowed to the left, and easterly to the right on *every* course.

(4.) The correction for Leeway is to be allowed *from* the wind.

Example.

Hours	Courses.	Knots	10ths.	Winds.	Lee-way.	Remarks.
1	S. E.	4	8	E. N. E.	1¼	A point of land in Lat. 46° 55′ N., Long. 52° 30′ W., bearing N. N. W ½ W., distant 25 miles.
2		4	7			
3		4	8			
4		4	6			
5	E. ½ S.	4	3	N. N. E.	1	
6		3	9			
7		4	2			
8	E. S. E.	4	6	N. E.	1½	Variation 1¾ W.
9		4	8			
10		5	1			
11	S. E. *b*. E.	4	9	E. N. E.	¾	
12		4	7			
1		3	9			
2		4	1			A current set by Compass. } E. ½ S. 39.6 miles from the time the departure was taken to the end of the day.
3		4	0			
4	N. *b*. E.	4	1	E. N. E. ½ E.	1½	
5		3	9			
6		4	6			
7		3	8			
8	N. E. *b*. N.	3	9	E.	½	
9		3	9			
10	N. E. *b*. E. ½ N.	4	2	S. E. *b*. E.	1¼	
11		4	7			
12		4	8			

Courses.	Dist.	Diff. Lat.		Dep.	
		N.	S.	E.	W
S. 4¼ E.	25		16.8	18.5	
S. 4½ E.	18.9		12.0	14.6	
N. 7¾ E.	12.4	.6		12.4	
S. 6¼ E.	14.5		4.9	13.7	
S. 6 E.	21.6		8.3	20.0	
N. 2¼ W.	16.4	14.9			7.1
N. ¾ E.	7.8	7.7		1.1	
N. 1½ E.	13.7	13.1		4.0	
N. 6¾ E.	39.6	9.7		38.4	
		46.0	42.0	122.7	7.1
		42.0		7.1	
		4.0		115.6	

To find the true Courses.

The ship's position from the land was
S. S. E. ½ E. or 2½ pts. *l.* S.
V. 1¾ *l.*
S. 4¼ E.
25

(2)
4 *l.* S.
L. 1¼ *r.*
2¾ *l.*
V. 1¾ *l.*
S. 4½ E.
18.9

(3)
7½ *l.* S.
L. 1 *r.*
6½ *l.*
V. 1¾ *l.*
S. 8¼ E.
16
N. 7¾ E.
12.4

(4)
6 *l.* S.
L. 1½ *r.*
4½ *l.*
V. 1¾ *l.*
S. 6¼ E.
14.5

(5)
5 *l.* S.
L. ¾ *r.*
4¼ *l.*
V. 1¾ *l.*
S. 6 E.
21.6

(6)
1 *r.* N.
L. 1½ *l.*
½ *l.*
V. 1¾ *l.*
N. 2¼ W.
16.4

(7)
3 *r.* N.
L. ½ *l.*
2½ *r.*
V. 1¾ *l.*
N. ¾ E.
7.8

(8)
4½ *r.* N.
L. 1¼ *l.*
3¼ *r.*
V. 1¾ *l.*
N. 1½ E.
13.7

The current set. } E. ½ S = 7½ *l.* S.
V. 1¾ *l.*
S. 9¼ E.
16
N. 6¾ E.
39.6

Open Norie, Table I.; above 4¼ pts., and opposite 25 miles of dist., we observe 16.8 Lat., and 18.5 dep., and as the ship is sailing on a S. and E. course, the Lat. is written in the S. column, and the Dep. in the E. To take out for such distances as occur in succeeding courses, proceed thus :—

4½ pts. and dist. 189 miles = d. lat. 119.9, and dep. 146.1, now remove the decimal point one place to the left, then 18.9 = d. lat. 11.99 and dep. 14.61. There is no need to write down both the decimal places, but if, as in the case with the d. lat., the second decimal fig. exceed 5, add 1 to the first, and our Lat. is 12; if, as in the dep., the second figure is below 5, reject it.

For any distance above 30 miles, such as the last course :

Course 6¾ pts. distance 39 = d. lat. 9.5 dep. 37.8
Dist. 6 miles = d. lat. 1.5 dep. 5.8
Removing the decimal point one place to the left, .6 = d. lat. .2 dep. .6
Therefore, Co. 6¾ pts., dist. 39.6 = d. lat. 9.7 dep. 38.4

To find Lat. in
D. Lat. left 46.55 N.
D. Lat. 4 N.
Lat. in 46.59

To find D. Long.
Lat. left 46.55
Lat. in 46.59
2 | 93.54
Mid. Lat. 46.57
90
Com. Mid. Lat. 43.3

To find Long. in
Long. left 52.30 W.
D. Long. $\frac{170}{60}$ = 2.50 E.
Long in 49.40 W.

Turning to Table II., with 43° as a course and dep. 115.6 in its own column, we obtain a dist. of 170 miles, the diff. of Long.

To find the course and distance made good :—Turn up Table II. and find 4.0 and 115.6 abreast of each other. The course is N. 88 E., and the dist. 116 miles.

Hours	Courses.	Knots	10-ths	Winds.	Lee-way.	Remarks.
1	S. E. ½ E.	2	3	E. N. E. ½ N.	1½	A point of land in Lat. 47° 35′ S., Long. 179° 6′ E., bearing by Compass, W. S. W. ¼ S., distant 18 miles.
2		2	4			
3		2	5			
4		4	0			
5	E. S. E. ½ S.	4	2	N. E. ½ E.	1¾	
6		4	3			
7		4	5			
8		4	6			
9	N.	4	7	W. N. W.	2	
10		4	8			
11		4	9			
12		4	9			
1	N. W. ¾ W.	5	2	W. S. W. ¾ S.	0	Variation 2¼ pts. E.
2		5	3			
3		5	4			
4		5	6			
5	W. S. W. ½ S.	5	7	N. W. ½ W.	2¼	A current set by Compass. } W. N. W. ½ N.
6		5	8			
7		5	9			
8		5	9			
9	S. *b* W. ¾ W.	6	0	S. E. ¼ E.	2¼	36.4 miles from the time the departure was taken to the end of the day.
10		6	2			
11		6	3			
12		6	4			

The ship's bearing E. N. E. ¼ N = 5¾ pts. r. N.
Var. 2¼ r.
East.
18

Courses.	Dist.	Diff. Lat.		Dep.	
		N.	S.	E.	W.
East.	18			18	
S. ¾ E.	11.2		11.1	1.6	
S. 1½ E.	17.6		16.8	5.1	
N. 4¼ E.	19.3	13.0		14.3	
N. 2½ W.	21.5	19.0			10.1
S. 5½ W.	23.3		11.0		20.6
S. 6¼ W.	24.9		8.4		23.4
N. 3¼ W.	36.4	29.2			21.6
		61.2	47.3	39.0	75.7
		47.3			39.0
		13.9			36.7

(2) 4½ l. S.
L. 1½ r.
3 l.
V. 2¼ r.
S. ¾ E.
11.2

(3) 5½ l. S.
1¾ r.
3¾ l.
V. 2¼ r.
S. 1½ E.
17.6

(4) 0
L. 2 r.
V. 2¼ r.
N. 4¼ E.
19.3

(5) 4¾ l. N.
V. 2¼ r.
N. 2½ W.
21.5

(6) 5½ r. S.
L. 2¼ l.
3¼ r.
V. 2¼
S. 5½ W.
23.3

(7) 1¾ r. S.
L. 2¼ r.
V. 2¼ r.
S. 6¼ W.
24.9

The current set W. N. W. ½ N. = 5½ l. N.
2¼ r.
N. 3¼ W.
36.4

Lat. left	47° 35′	S.
D. Lat.	14	N.
Lat. in	47 21	
	47 35	
	2)94 56	
Mid. Lat.	47 28	
	90	
Comp. mid. Lat.	42 32	

Long. left	179° 6′	E.
D. Long.	54	W.
Long. in	178 12	E.

Course 43° and dep. 36.7 give us 54 miles as a difference of Longitude.

Course N. 69° W., distance 39 miles.

EXAMPLES FOR EXERCISE.

(1.)

Hours	Courses.	Knots.	10ths.	Winds.	Lee-way.	Remarks.
1	W. *b*. N.	6	3	N. *b*. W.	2½	A point of land in Lat. 16° 55′ S., Long. 19° 4′ W. bearing by Compass E. *b* N. ¼ N. distant 20.5 miles.
2		5	2			
3		7	0			
4		3	9			
5		4	2			
6	E. N. E.	8	1	N.	½	
7		6	6			
8		2	7			
9		7	4			
10		5	2			
11	E. ¼ S.	3	0	S. *b*. E.	¾	
12		4	9			Variation 2¼ pts. E.
1		2	3			
2	W. ¾ N.	6	4	S. S. W.	1¼	
3		3	7			
4		4	9			A current set by Compass. } S.W.*b*.W.
5		4	0			
6	S. S. E.	4	8	E.	1	
7		6	6			20 miles from the time the departure was taken to the end of the day.
8		8	7			
9		5	4			
10	W. N. W. ¼ N.	4	3	N.	1½	
11		3	0			
12		7	8			

(2.)

Hours	Courses.	Knots	10ths.	Winds.	Lee-way.	Remarks, &c.
1	S. S. W. ¼ W.	3	9	W. ¼ N.	1	A point of land in Lat. 51° 25′ N., Long. 9° 29′ W. bearing by Compass N. E. ¼ N. distant 16 miles.
2		4	4			
3		4	8			
4		5	2			
5		5	7			
6	N. *b* W. ½ W.	6	0	W. *b* N.	1½	
7		5	5			
8		5	1			
9		4	7			
10		4	0			
11	S. *b*. E. ½ E.	4	3	S. W. ½ W.	1¼	
12		4	7			Variation, 1¾ pts. W.
1		5	0			
2		5	5			
3	S. W.	5	1	W. N. W.	1	
4		4	8			
5		4	9			A current set by Compass. } N.N.W.
6		4	5			
7		4	1			
8	W. *b* S.	4	0	N.	0	23.8 miles from the time the departure was taken, to the end of the day.
9		3	7			
10		3	4			
11	S. W. *b*. W ½ W.	3	0	N. W.	½	
12		3	3			

(3.)

Hours	Courses.	Knots	10ths.	Winds.	Lee-way.	Remarks.
1	S. W. ¼ W.	5	7	S. S. E.	1	A point of land in Lat. 10° 12′ N., Long. 76° 30′ E., bearing by Compass N. *b* W. ½ W. distant 17 miles.
2		5	3			
3		5	6			
4	W. S. W.	6	4	Do.	1¼	
5		6	8			
6		4	5			
7	W. ½ S.	4	2	S. *b* W.	2	
8		4	3			
9	W. *b* N.	5	9	S. S. W.	1¼	
10		4	2			
11		3	9			
12		5	7			
1		5	6			
2	W. S. W.	6	2	S. *b* E.	0	Variation 1½ pts. E.
3		6	7			
4		6	3			
5	W. N. W.	6	6	S. S. W.	1½	
6		4	4			A current set by Compass. S. W. *b* W. 30 miles from the time the departure was taken to the end of the day.
7		4	9			
8		4	8			
9	S. *b* W.	5	3	W.	1½	
10		5	4			
11		4	7			
12		5	8			

(4.)

Hours	Courses.	Knots	10ths.	Winds.	Lee-way.	Remarks.
1	W. *b* S. ½ S.	4	6	N. N. W.	1	A point of land in Lat. 50° 40′ N., Long. 15° 42′ W., bearing by Compass N. E. *b* E. distant 21 miles.
2		4	3			
3		3	7			
4		3	6			
5		3	4			
6	W.	4	2	N. ½ E.	¾	
7		3	8			
8		3	5			
9	W. S. W.	4	4	N. W.	2	
10		4	1			
11	S. S. W. ¼ W.	6	2	N. N. E.	0	
12		5	7			
1		6	4			Variation 2¼ W.
2		6	2			
3	S. *b* E. ¾ E.	5	8	N. E.	½	
4		5	5			
5		4	3			
6	S. E. *b* S.	6	0	E. N. E.	2½	A current set by Compass. E. *b* N. ½ N. 15.5 miles from the time the departure was taken to the end of the day.
7		5	7			
8		5	3			
9	S. S. E. ¼ E.	4	3	E. N. E. ½ N.	1½	
10		5	1			
11		5	4			
12		4	7			

LOGARITHMS.

Remarks.—(1.) In finding the log. of any number, the first thing to determine is its index.

(2.) The index is *one less* than the number of *whole* numbers. Thus,

4687325 = Index 6
468732.5 = ... 5
46873.25 = ... 4
4687.325 = ... 3
468.7325 = ... 2
46.87325 = ... 1
4.687325 = ... 0
.4687325 = .. $\bar{1}$ or borrowing 10 = 9 the arithmetical complement.
.04687325 = ... $\bar{2}$ = 8
.004687325 = ... $\bar{3}$ = 7
.0004687325 = ... $\bar{4}$ = 6
and so on.

MULTIPLICATON.

Multiply 2634.25 by 6873 by common logs.

$$
\begin{array}{rcl}
2634.25 & = & 3.420657 \\
.6873 & = & \bar{1}.837146 \\
\hline
\textit{Ans.}\ 1810 & = & 3.257803
\end{array}
$$

After placing the numbers under each other, and noting their indices, we open Norie, Table XXIV., and find the log. of 2634 to be 420616.

Now, in this table, we cannot take out the log. for more than four figures directly; and as we have other two to account for, we proceed thus:—Take out from the diff. column opposite 263, the number 165. Multiply this by the remaining figures 25, and we get 4125 as a product; cut off from the right as many figures as were sought for, in this case two, and add the remainder 41 to the log. 420616, the sum will be the log for 2634.25. After taking out the second log., *add.* In doing this, the student, if he be unacquainted with algebra, will probably not understand how the index 3 is obtained. This we will endeavour to explain as briefly as possible. In using logarithms, we have two kinds of indices, viz., *positive* (+), and *negative* (—). Referring to the example, the first index is positive, the second negative. The distinction between them may be easily understood, if, in our own minds, we permit the

$$
\begin{array}{r}
165 \\
25 \\
\hline
825 \\
330 \\
\hline
4125
\end{array}
$$

word *credit* to signify a *positive* index, and *debt* a *negative* one. Going back to our addition, we meet with 12. The 2 is put down and the 1 carried forward to our *credit;* the index however, to which it is to be added, being negative, represents our *debt*, and, therefore, the two are cancelled, leaving the first index as a balance Instead of using $\bar{1}$ as the index, some prefer to work with 9, in which case, after adding the indices together, the borrowed 10 would be returned.

To obtain our answer, search the logs. till you find 257803. In this case you will not be able to do so. Take out the *next less* log. to our own, which will be 257679 ; against this is the number 181, and the column in which the log. stands is 0.

These four figures 1810 will form the answer. The next question is, how many of them are whole numbers? This is determined by the index, which requires the answer to consist of *one more* whole number than it indicates.

Our index is 3, therefore the four figures 1810 will be four whole numbers.

Multiply 26834.159 by .000020051 by common logs.

26834.159 = 4.428688
.000020051 = $\bar{5}$.302136
.5380 = $\bar{1}$.730824

log. 2683 = 428621 diff. 162
diff. for 4159 = + 67 × 4159
true log. = 428688
8318
24954
4159
673758

log. 2005 = 302114 diff. 217
diff. for 1 = + 22 × 1
true log. = 302136
217

In the above example, the result being negative 1 shews that the answer must be less than one whole number, in fact that the four figures are only a decimal portion of 1.

Multiply 1000345 by 100.345 by common logs.

1000345 = 6.000149
100.345 = 2.001495
Ans. 100379398 = 8.001644
001301
432)3430(79398
3024
4060
3888
.1720
1296
4240
3888
.3520
3456

log. 1000 = 000000 diff. 432
diff. for 345 + 149 × 345
true log. = 000149
2160
1728
1296
149040

log. 1003 = 001301 diff. 432
diff. for 45 = + 194 × ·45
true log. = 001495
2160
1728
19440

In this example the index being positive 8, requires us to have nine whole numbers for our answer. We find the next less log. which gives us 1003, that log we write beneath ours and subtract it; to this difference we add 0 and divide by the Tabular diff.. the quotient is 7; we go through the operation of multiplication and subtraction, add another 0 and get the sixth figure, and by repeating this operation, we obtain the amount of whole numbers required.

EXAMPLES FOR EXERCISE.

(1.) Multiply 96710 by .00617 by common logs.
(2.) Multiply 8603752 by .006047 ... ...
(3.) Multiply 26.85006 by 6214 ... ...
(4.) Multiply 653.7142 by .003816 ... ...
(5) Multiply 836054.320 by 73.0608 .. ...
(6.) Multiply 506.384 by 3.068 .. ...
(7.) Multiply 3000654 by 28643 ... ...
(8.) Multiply 9610063 by .000230 ... ...
(9.) Multiply 346182 by .21643 ... ...
(10.) Multiply .07536 by .0058 ... ...
(11.) Multiply 163.68503 by .010065 ... ...
(12.) Multiply 2179368 by 1638.007 ... ...

DIVISION.

Remarks.—(1.) To find the log. of any number, proceed in the same manner as in Multiplication.

(2.) *Subtract* the log. of the second number from the log. of the first.

(3.) If the index of the *second* number is positive, *change* it to negative before applying it to the index of the first, and if negative *change* it to positive.

Divide 26843 by .003010 by common logs.

```
        26843  = 4.428831          log. 2684 = 428782 diff. 162
       .003010 = 3̄.478566          diff. for 3 =  + 49    ×   3
                 ────────                       ──────    ─────
Ans. 8917938   = 6.950265                       428831      486
                   950219
                   ──────
                   49)460(938
                      441
                      ───
                       190
                       147
                       ───
                        430
                        392
                        ───
```

Here the Index to the second number is negative 3, but following the rule, we have changed it to positive 3. The index to the first number being positive, the two are added, the sum being positive 7, but having borrowed 1, the correct index is positive 6.

Divide .0574682 by 34.03152 by common logs.

$$\begin{array}{rl} .0574682 & = \bar{2}.759428 \\ 34.03152 & = 1.531881 \\ \hline .001688 & = \bar{3}.227547 \end{array}$$

$$\begin{array}{lrr} \log 05746 = & 759366 & \text{diff. } 76 \\ \text{diff. for } 82 & =+62 & 82 \\ \hline & 759428 & 152 \\ & & 608 \\ \hline & & 6232 \\ \log 3403 = & 531862 & \text{diff. } 128 \\ \text{diff. for } 152 = & +\ 19 & 152 \\ \hline & 531881 & 256 \\ & & 640 \\ & & 128 \\ \hline & & 19456 \end{array}$$

Positive 1 becomes negative 1. The first index being also negative, their sum is *nègative* 3.

Divide 36845.12 by 36.0086.

$$\begin{array}{rl} 36845.12 & = 4.566380 \\ 36.0086 & = 1.556405 \\ \hline \text{Ans. } 1023 & = 3.009975 \end{array}$$

In this case it is negative 1 from positive 4.

$$\begin{array}{lrr} \log. 3684 = & 566320 & \text{diff. } 118 \\ & 60 & 512 \\ \hline & 566380 & 236 \\ & & 118 \\ & & 590 \\ \hline & & 60416 \\ \log 3600 = & 556302\ \text{diff.} & 120 \\ & 103 & 86 \\ \hline & 556405 & 720 \\ & & 960 \\ \hline & & 10320 \end{array}$$

EXAMPLES FOR EXERCISE.

(1.) Divide .6180594 by .000026108 by common logs.
(2.) Divide 41683260 by 26.16342 ... ...
(3.) Divide 62.060 by 37.821 ... ...
(4.) Divide 5680.763 by .0100637 ... ...
(5.) Divide 308.21600 by .90004 ... ...
(6.) Divide 5.68460 by 7684 ... ...
(7.) Divide 7320 by .0200 ... ...

(8.) Divide 1638.6006 by .031690 by common logs.
(9.) Divide 62.8709 by .09782 ... ...
(10.) Divide 260387 by 3566 ... ...
(11.) Divide 26.86105 by .02636105 ... ...
(12.) Divide 764386 by 5498 ... ...

PARALLEL SAILING.

The student will understand that by sailing on a parallel of latitude, he does not change his latitude, but only his longitude, and the question is, how many miles of longitude have I run down in making a certain known distance or departure?

Example.—In latitude 35° 49′ the departure made good was 46.3 miles, require the diff. of longitude?

Formula. Log. diff. Long. = Log. dep. + Log. Sec. Lat. — 10
Log. dep. 46.3 = 1.665581
Log. sec. 35.49 = .091036

Diff. long. 57.1 miles = 1.756617

As we have to reject 10, the shortest way is to throw off 10 from the secant.

Examples for Exercise.

(1.) In latitude 42° 13′, the departure made good was 126.4 miles, required the difference of longitude.

(2.) In latitude 64° 16′ the departure made good was 265.7 miles, required the difference of longitude

(3) In latitude 51° 28′ the departure made good was 70.9 miles, required the difference of longitude.

(4.) In latitude 58° 45′ the departure made good was 126.9 miles, required the difference of longitude.

(5.) In latitude 34° 30′ the departure made good was 180 miles, required the difference of longitude.

(6.) In latitude 60° 12′ the departure made good was 127.6 miles, required the difference of longitude.

TO FIND THE LATITUDE BY A MERIDIAN ALTITUDE OF THE SUN.

In this and most of the succeeding problems, the student will require the aid of the Nautical Almanac.

The elements that are there furnished us, the Sun's declination, and the equation of time for instance, are computed for the meridian of Greenwich, or for longitude 0°. Consequently, if we take an observation in any other longitude, we are compelled to find the time at Greenwich for the moment the observation was made. This is done by turning the longitude of the place into time, and adding it to the time at ship if West, but subtracting it if East. Thus if a sight be taken at noon at ship in longitude 90° West, the time at Greenwich will be 6 P.M. Again, if a sight be taken at noon at ship in longitude 90° East, the time at Greenwich will be 6 o'clock A.M.

Moreover, the elements in the Nautical Almanac are computed for the Greenwich astronomical day, binding us to use the same kind of day in all our observations. This day commences at noon, and is continued unbroken through 12 hours, 13 hours, 14 hours, &c., up to 24 hours, or the following noon. The civil day is the one used in every-day life. It begins at midnight, is counted up to 12 hours, recommences at 1 hour, and ends at 12 hours or midnight, and is 12 hours in advance of the astronomical day. The distinction between the civil and astronomical day is often very puzzling to the student; we will endeavour to make it clear to him. Suppose we take an observation on January 4th at 9 A.M. This is civil. time, for the day here expressed commenced at midnight, and the sight was taken at 9 hours from midnight; but it was stated above that we must refer all our observations to the astronomical day. The first question is, when did the astronomical day commence?

Ans. At the previous noon.
How many hours have passed since then?

Ans. There were 12 hours from noon to midnight, and 9 hours from midnight to 9 A.M., consequently 21 hours have elapsed.

The astronomical day is January 3d, for as it is 12 hours behind the civil day, 3 hours must elapse ere the fourth astronomical day begins. Thus follows the rule. If a *forenoon* sight be taken, add 12 hours to the time at ship, and throw off one day, and the civil date January $4^{d}\ 9^{h}\ 0^{m}\ 0''$, becomes January $3^{d}\ 21^{h}\ 0^{m}\ 0''$ astronomical date.

Again, suppose a sight to be taken on January 4th at 3 P.M. Now this is an afternoon sight, and this portion of the civil day, agrees with the astronomical; for as the astronomical day commenced at noon, it is 3 hours astronomical time as well as civil, hence, with a P.M. observation, no alteration is made.

On September 10th, at $10^{h}\ 30^{m}$ A.M., an observation was taken on board of ship in longitude 40° 20′ W.; required the Greenwich time.

	d h m	
Civil date at ship	10 10 30 A.M.	Long. 40° 20′ W.
	12	4
Astronomical date at ship	9^{d} 22 30	60)161 20
Long. in time W.	+ 2 41 20″	2^{h} 41^{m} 20″
Greenwich date.	10 1 11 20	

On July 6th, at 2^{h} 40^{m} P.M., at ship in long. 85° 50′ E; required the Greenwich time.

	d h m	
Time at ship	6 2 40	Long. 85° 50′ E.
		4
Long in time E.	— 5 43 20	60)343 20
Greenwich Time.	5 20 56 40	5^{h} 43^{m} 20″

1859, January 6th, in longitude 19° 47′ W. the observed mer. alt. of the ☉ was 36° 18′ 45″ bearing north, index error + 55″, height of the eye 14 feet. Required the latitude.

	d h m ″				Hourly diff.
App. ship time, Jan.	6 0 0 0	Long. 19° 47′ W.	☉'s Dec. S.	22° 32′ 2″	— 18.42
Long. in time, W.	1 19 8	4	Cor.	24	1.3
App. Green. time,	6 1 19 8	60)79 08	Sun's Dec.	22 31 38	5526
					1842
		1 19 8			
					23.946

To the apparent ship time (noon) add the longitude in time, being west, and the sum is the apparent Greenwich time. Turn to page 1 of the Nautical Almanac for January, and note the Sun's declination on the 6th, also its "diff. for 1 hour;" next observe whether the declination is increasing or decreasing. In this case it is decreasing, and we note that fact by putting the negative sign before the hourly difference. Now this question presents itself, since the declination changes 18.42″ in 1 hour, how much does it change in 1^{h} 19^{m} 8″? First, divide the minutes by 6; thus 6 is contained in 19 three times nearly. Set the 3 under the difference as a decimal, to which prefix the 1 hour, and then proceed as in common multiplication.* The resulting figures are 23946, but as we have two decimal places in the multiplicand, and one in the multiplier, in all three, 3 figures are to be marked off from the right, leaving 24″ nearly as the correction to be applied to the declination, subtractive because the declination is decreasing.

---

* The reason for this will be readily seen by those who are acquainted with decimal arithmetic. Thus 19′ is 19-60ths of an hour, or as a decimal = 190-60ths = .3 nearly. Instead of adding a cipher to the 19, we throw off that from the 60 and divide; the result is the same.

		°	′	″	
Obs. alt. ⊙̲ N. ...		36	18	45	
I. E.	+			55	
		36	19	40	
Dip for 14 feet, Table V.,	—		3	36	
		36	16	4	
Refraction, Table IV. , ...	—		1	17	
		36	14	47	
Semi-Diameter, N. A., page II.,	+		16	18	
		36	31	05	
Parallax, Table VI., ...	+			7	
True Alt.		36	31	12	
		90			
Zenith Distance, ...		53	28	48	S.
True Declination, ...		22	31	38	S.
Latitude,		76	00	26	S.

To correct the altitude.

(1.) Apply the Index Error according to its sign.

(2.) Subtract the dip for the height of eye. (Table V.)

(3.) „ Refraction for alt. („ IV.)

(4.) Add the Sun's semi-diameter from page II. Naut. Alm., if the lower limb be observed (⊙̲), but subtract it if the upper (⊙̅).

(5.) Add the Sun's parallax in alt. (Table VI.)

(6.) Subtract the true alt. so found from 90°, the difference is the meridian zenith distance, and is S. if the Sun's bearing is N., and N. when the bearing is S.

(7.) If the zenith distance and declination be of the same name, their sun is the latitude; otherwise their difference is to be taken, and the name of the greater quantity will give the name to the latitude.

1859. February 1st, in longitude 153° 40′ E. The observed mer. alt. ⊙̅ was 62° 10′ 15″ bearing S.; Index error — 2′ 12″, height of the eye 20 feet. Required the latitude.

	d h m ″				″
App. ship time, Feb.	1 0 0 0	Long. 153° 40′ E.	⊙'s Dec. S.	17° 26′ 35″	— 42.20
Long. in time, E.	10 14 40	4	Cor.	— 9 42	13.8
A. G. T., January	31 13 45 20	60)614 40	T. Dec.	17 16 53	33760
					12660
		10 14 40			4220
					60)582.360
					9 42

Here we have an observation made in East longitude, which is turned into time, and subtracted from the time at ship. In doing this we find the apparent time at Greenwich to be on January 31st. The declination must therefore be taken out for that day, and the hourly difference multiplied by 13ʰ 45ᵐ, or dividing the minutes by 6, by 13.8 nearly. After pointing off the three decimal places, we have 582″ remaining, which is equivalent to 9′ 42″, and as the declination is decreasing, this correction is subtracted.

Obs. Alt. $\overline{\odot}$ S.	62° 10′ 15″	
I. E.	— 2 12	
	62 8 3	
Dip for 20 feet, Table V. ...	— 4 17	
	62 3 46	
Ref. Table IV.	— 0 30	
	62 3 16	
Semi-diam. N.A. page II., Upper Limb	— 16 16	
	61 47 00	
Parallax, Table VI.	+ 4	
True Alt.	61 47 4	
	90	
Zenith Distance	28 12 56	N.
True Declination	17 16 53	S.
Latitude	10 56 3	N.

1859. March 21st, in long. 77° 30′ E., the observed meridian alt. of the $\underline{\odot}$ was 47° 28′ 40″ bearing N.; Index error + 2′ 15″; height of the eye 23 feet. Required the latitude.

	d h m ″		° ′ ″		° ′ ″	″
A.S.T., March	21 0 0 0	Long.	77 30 E.	⊙ dec. S.	0 15 0	59.22
Long. in time E.	5 10 0		4		— 18 33	18.8
A.G.T..	20 18 50 0		60)310 00	N.	0 3 33	47376
						47376
			5 10			5922
						60)1113.336
						18 33

In this example the correction to be taken from the declination is greater than the declination itself. This shews that the Sun must have crossed the equator since last noon, and that the declination is 0° 3′ 33″ N.

	°	′	″	
Observed alt. $\underline{\odot}$ N.	47	28	40	
Index error .	+	2	15	
	47	30	55	
Dip . .	—	4	36	
	47	26	19	
Refraction .		—	52	
	47	25	27	
Semi-Diam.	+	16	5	
	47	41	32	
Parallax . .	+		6	
True alt. . .	47	41	38	
	90			
Zenith dist. .	42	18	22	S.
Declination .	0	3	33	N.
Latitude . .	42	14	49	S.

EXAMPLES FOR PRACTICE.

(1.) 1859. April 6th, in long. 54° 30′ E., the obs. mer. alt. $\underline{\odot}$ bearing N. was 34° 14′ 30″; H. E. 16 ft.; I. E. + 1′ 26″. Required the latitude.

(2.) ... May 20th, in long. 87° 35′ W., the obs. mer. alt. $\underline{\odot}$ bearing S. 61° 28′ 40″; H. E. 16 ft.; I. E. — 2′ 15″. Required the latitude.

(3.) 1859. June 14th, in long. 122° 36′ E., the obs. mer. alt. $\overline{\odot}$ bearing N. 72° 28′ 15″; H. E. 14 ft.; I. E. — 6′ 15′. Required the latitude.

(4.) ... July 27th, in long. 16° 30′ W., the obs. mer. alt· $\underline{\odot}$ bearing N. 27° 15′ 10″; H. E. 18 ft.; I. E· — 2′ 50″. Required the latitude

(5.) ... August 7th, in long. 52° 10′ W., the obs. mer. alt. $\underline{\odot}$ 61° 9′ 30″, bearing S.; H. E. 18 ft.; I. E. — 3′ 20″. Required the latitude.

(6.) .. Sept. 23d, in long. 95° 45′ W., the obs. mer. alt. $\underline{\odot}$ 35° 14′ 30″, bearing S.; H.E. 16 ft.; I.E. — 3′ 18″. Required the latitude.

(7.) ... Oct. 1st, in long. 76° 20′ E., the obs. mer. alt. $\overline{\odot}$ 58° 21′ 10″, bearing N.; H. E. 14 ft.; I. E. — 4′ 15″. Required the latitude.

(8.) ... Nov. 12, in long. 135° 12′ W., the obs. mer. alt. $\underline{\odot}$ 36″ 24′ 55″, bearing S.; H. E. 11 ft; I. E. — 8′ 45″. Required the latitude.

(9.) ... Dec. 2, in long. 125° 32′ E., the obs. mer. alt. $\overline{\odot}$ 54° 56′ 20″, bearing S.; H. E. 22 ft.; I. E. + 2′ 10″. Required the latitude.

ADDITIONAL FOR ONLY MATE.

MERCATOR'S SAILING.

Required the course and distance by Mercator's sailing :—

		(From Table III.)			
Lat. A.	51° 28′ N.	mer. pts.	3614	Long. A.	9° 29′ W.
Lat. B.	48 23 N.	do.	3326	B.	4 29 W.
	3 5	mer. diff. of Lat.	288		5 00
	60				60
Proper diff. of Lat.	185				300 diff. of Long.

Formulæ.

To find the Course.

Log. Tan. Course = log. diff. Long. — Log. mer. diff. Lat. + 10

To find the Distance.

Log. Dist. = Log. prop. diff. Lat. + Log. Sec. Course — 10

Dif. log. 300=2.477121	P. d. lat. 185 = 2.267172
M. D. L. 288=2.459392	Sec. 46° 10′ = 0.159541
(Table XXV.) Co. S. 46° 10′ E. 10.017729	Dist. 267.1 miles 2.426713

Both latitudes being N., subtract and reduce to miles. Take out from Table III. the meridional parts for each latitude, and subtract likewise. The longitudes being of the same name, subtract and reduce to miles. As the ship is going from a greater N. latitude to a less, she must sail southward, and from a greater W. long. to a less, easterly. Therefore her course must lie between the S. and E.

Lat. A	13° 45′ N. mer. pts.	833	Long. A 6° 15′ E.
Lat. B	26 37 S. mer. pts.	1658	Long. B 8 10 W.
	40 22	2491 mer. diff. lat.	14 25
	60		60
Prop. diff. lat.	2422		865 diff. long.

Diff. long. 865=2.937016	Prop. diff. lat. 2422=3.384174
Mer. diff. lat. 2491=3.396374	Sec 19° 9′= .024723
Course S. 19° 9′ W. 9.540642	Distance 2563 miles 3.408897

The latitudes and longitudes being of opposite names, take the sum in each, and proceed as before. There is no occasion to write Radius (10) in the computation, it can be applied mentally.

EXAMPLES FOR EXERCISE.

Find the course and distance by Mercator's Sailing, in each of the following examples.

(1.)	Lat. A.	51° 28′ N.	Long. A.	0° 0′
	B.	30° 47′ N.	B.	13° 29′ W.
(2.)	Lat. A.	2° 37′ N.	Long. A.	110° 42′ W.
	B.	0° 0′	B.	120° 36′ W.
(3.)	Lat. A.	51° 29′ N.	Long. A.	80° 20′ E.
	B.	57° 9′ N.	B.	96° 13′ E.
(4.)	Lat. A.	13° 42′ S.	Long. A.	61° 41′ W.
	B.	6° 18′ N.	B.	54° 39′ W.
(5.)	Lat. A.	54° 39′ S.	Long. A.	11° 18′ W.
	B.	37° 54′ S.	B.	5° 14′ E.
(6.)	Lat. A.	3° 30′ N.	Long. A.	2° 33′ W.
	B.	4° 10′ S.	B.	23° 45′ E.
(7.)	Lat. A.	16° 50′ N.	Long. A.	180° 0′ E.
	B.	18° 23′ N.	B.	161° 10′ E.
(8.)	Lat. A.	17° 26′ S.	Long. A.	13° 25′ W.
	B.	13° 45′ N.	B.	20° 10′ E.

TIDES.

(Method as required at the Local Marine Board of Aberdeen.)

Remarks.—The elements required from the Nautical Almanac are—(1.) The Moon's meridian passage for the given day. (2.) The difference between this day and the preceding, if the longitude be East, but the succeeding if West. (3.) The Moon's semi-diameter. (4.) Equation of time from p. 2, noting its application to mean time.

The correction for longitude is applied in the usual way + if West, — if East. If the time of H. W. exceed 12 or 24^h, diminish the ☽'s passage by half or the whole variation of the given and preceding day.

1859. January 8. Find the time of high water, A.M. and P.M. at New Calabar River (long. 7° E.). Change tide 5^h 0^m, appointed time.

	h m		☽'s S. D.	Eq. of time,
Naut. Alm. p. 4, ☽'s Mer. Pass. Jan. 8.	3 19	Mer. Pass. 7. 2.37	p. 3.	p. 2.
Table xvi. { long. 7° E. m Daily Variation 42 } =	— 1	Do. 8. 3.19	14′ 56″	m 7
	3 18	Daily variation 42		Subt. from mean time.

	h m	
Mean time,	3 18	
Eq. time,	— 7	
App. time,	3 11	with this time and the ☽'s S. D. 14.56, we obtain the 2d cor. from xvi.* — 49
	2 29	
Change tide,	5 0	
	7 29	P.M. tide.
Half daily variation,	— 21	
	7 8	A.M. tide.

1859. Feb. 14th. Find the time of high water, A.M. and P.M., at Halifax, (long. 63° 38′ W). Change tide 8^h 0^m app. time.

h m	h m	☽'s S. D.	Eq. of Time,
14th 9 53	13th 8 49	16′ 36″	m
15th 10 54	14th 9 53		14
			— M. T.
1 1	1 4		
60	60		
61	64		

h. m.
☽'s Mer. Pass. Feb. 4 9 53
Long. 63° 38′ W. } = + 10
Daily variation 61 }

10 3
— 32 { Subtract half the diff. of the passages of the 14th and 13th, because 10^h 3^m added to the change tide 8^h 0^m, is greater than 12^h.

9 31

h m
Mean time, 9 31 }
Eq. time, — 14 }
} = + 34
App. time, 9 17 }
☽'s S. D. 16 36 }

10 05
Change tide, 8 0

18 5
12

6 5 P.M. tide.
Half daily variation, — 32

5 33 A.M.

1859. March 27th. Find the time of high water A.M. and P.M. at Sandy Hook, (long. 74° W.) Change tide 7^h 30^m app. time.

h m	h m	☽'s S. D.	E. T.
27th 19 42	26th 18 54	14 48	5 m
28th 20 28	27th 19 42		— M. T.
46	48		

d m
☽'s Mer. Pass. 27. 19 42
Long. 74° W. } = + 9
Daily var. 46 }

19 51
— 48 { Subtract the whole diff. of Pass. on 27th and 26th, because 19^h 51^m added to 7^h 30^m is more than 24 hours.*

19 3

---

* It is usual to work the question as wrought in Example 1, and if the tide hour is found to exceed 12 or 24 hours, to rework it by subtracting the half or whole daily variation of the given and preceding days and proceeding as before. But by following the plan shewn in the example, the student will save time, and will seldom have to correct himself.

			h	m	
Brought forward			19	3	
Mean time,	19	3			
Eq. time,	—	5			
			= —	32	
App. time,	18	58			
☽'s S. D.	14	48			
			18	31	
			7	30	
			26	1	
			24		
			2	1	P.M. tide.
				24	
			1	37	A.M.

The above questions are wrought according to the rules laid down in Norie; and at page 170 of that work, the student will find special reference with regard to the method employed in the latter examples,

EXAMPLES FOR EXERCISE.

(1.) 1859. April 18th, Find the time of high water A.M and P.M. at Queen Charlotte's Sound, (long. 174° 23′ E.) Change tide 9h 0m app. time.

(2.) ... May 9th, at Isle de Dieu (2 °20′ W.) Change tide 3h app. time.

(3.) ... June 12th, at Rio Janeiro (43° 12′ W.) Change tide 2h 40m app. time.

(4) .. July 24th, at Pernambuco (34° 52′ W.) Change tide 7h 15m app. time.

(5.) ... Aug. 4th, at Drontheim (10° 23′ E.) Change tide 2h 15m app. time.

(6.) ... Sept. 11th, at Bahia (38° 30′ W.) Change tide 4h 15m app. time.

(7.) ... Oct. 16th, at Simon's Bay (18° 21′ E. Change tide 3h 30m app. time.

(8.) ... Nov. 18th, at Port Jackson (151° 20′ E.) Change tide 8h 15m app. time.

(9.) ... Dec. 3d, at Port Louis, Mauritius (57° 29′ E) Change tide 12h 30m app. time.

TIDES.

(Method required at the English Ports).

1859.—Jan. 2d, required the time of high water A.M. and P.M. at Liverpool.

	h	m
Full and change at London Bridge, .	2	7
... ... Liverpool, . .	11	16
	+9	9

	h	m	
Jan. 1st,	12	45	Astron^{l}. time of high water at London Bridge.
	12		
Jan. 2d,	0	45	Civil do.
	+9	9	The Liverpool time of high water is 9^h 9^m later than the L. B.
	9	54	A.M. at Liverpool.
	h	m	
2d,	1	9	P.M. tide at London Bridge.
	+9	9	
	10	18	P.M. tide at Liverpool.

At page 515 of the Nautical Almanac, the time of high water, at the full and change of the Moon at London Bridge is 2^h 7^m, and at Liverpool 11^h 16^m. It is therefore evident that the time of H. W. is *later* by 9^h 9^m at Liverpool than at London Bridge, consequently, if we know what time it is high water at London Bridge on any day, by adding to it 9^h 9^m, we can find the time of high water at Liverpool. On pp. 512 and 513 is a register containing the times of high water at London Bridge for every day in the year, reckoned in astronomical time. To this we turn, and as we are to refer our tides to the civil day, we note down the *last* tide on the *preceding* day, and by taking 12 hours from it, and adding one day to it, we have 45 minutes after midnight, the A.M. tide at London Bridge on the 2d, to which add 9^h 9^m, and the time of high water at Liverpool is 9^h 54^m A.M. The first tide on the given day is the P.M. tide at London Bridge, to which add the constant, and the result is the P.M. tide at Liverpool.

Feb. 8th.—Find the time of H. W. at Ipswich A.M. and P.M.

h m	d h m
L. B. 2 7	7 17 10
	12
Ip. 30	8 5 10 A.M. at L. B.
— 1 37	— 1 37 Ipswich so much earlier.
	3 33 A.M. at Ipswich.
	d h m
	8 5 26 P.M. at L. B.
	— 1 37
	3 49 P.M. at Ipswich.

March 16th.—Find the time of H. W. at Leith Pier A.M. and P.M.

h m	d h m
L. B. 2 7	15 11 36 P.M. at L.B. on 15th.
	10
L. P. 2 17	11 46 P.M. at Leith on 15th, therefore there is no A.M. Tide at Leith on the 16th.
+ 10	
	d h m
	16 0 14 P.M. at L.B. on 16th.
	+ 10
	0 24 P.M. at Leith on 16th.

April 29th.—At Newcastle A.M. and P.M.

h m	d h m
L. B. 2 7	28 23 49
	12
New. 4 22	29—11 49 A.M. at L.B.
+2 15	2 15
	2 04 P.M. at Newcastle on 29th.
	d h m
	28 11 22 P.M. at L.B. on 28th.
	2 15
	29 1 37 A.M. at Newcastle on 29th.

May 14th.—Find the time of H. W. at Ostend.

	h m	d h m	
L. B.	2 7	14 0 14 P.M.	at L. B. on 14th.
		— 1 12	
Ost.	55	11 2 A.M.	at Ostend on 14th.
	— 1 12		
		d h m	
		14 12 38 A.M.	at L. B. on 15th.
		1 12	
		11 26 P.M.	at Ostend on 14th.

It would be of very little use to lay down rules for the last three examples. If the student will bear in mind the distinction between the astronomical and civil day, a very little ingenuity will enable him to solve all such questions.

Examples for Exercises.

Required the time of High Water A.M. and P.M.

(1.) 1859. June 8th, at Whitby.
(2.) ... July 16th, at Aberdeen Bar.
(3.) ... Aug. 22d, at Kingston Harbour.
(4.) ... Sept. 9th, at Banff.
(5.) ... Oct. 5th, at Milford Haven.
(6.) ... Nov. 26th, at Southampton.
(7.) ... Dec. 25th, at Cuxhaven.

VARIATION OF COMPASS BY AMPLITUDE.

Remarks.—(1.) If it be a rising amplitude (E.) add 12 hours to the ship time, and throw off one day, with a setting (W.), no alteration is to be made.

(2.) Apply the longitude in time, and find the Greenwich time.

(3.) Correct the ⊙'s dec. for this time.

(4.) Log. sin. true amp. = log. sin. dec. + log. sec. lat. — 10.

(5.) The true amp. is reckoned towards the N. if the dec. be N., and S. if the dec. be S.

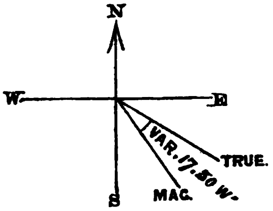
1859,—Jan. 11. At 8^h 26^m app. time at ship, in lat 54° 40′ S., long. 33° 17′ W.; the sun's magnetic amplitude was E. 57° 33′ S. Required the variation.

	d	h	m	″
App. time at ship	10	20	26	
Long. in time W. +		2	13	8
App. Green. time	10	22	39	8

°	′	
Long. 33	17	W.
	4	
60)133	08	
2	13	8

	°	′	″		″
⊙ Dec. S.	21	59	57	—	22.76
	—	8	37		22.7
	51	51	28		15932
					4552
					4652
					60)516.652
					8 37

	°	′			
Sin.	21	51	=		9.570751
Sec.	54	40	=		.237823
True Amp. E.	40	3	S. =	Sin.	9.808574
Mag. Amp. E.	57	33	S.		
Var.	17	30	W.		



To determine the variation, the student must suppose himself to be standing at the centre of the compass, looking at the bearings. If the true is on the left of the magnetic, the variation is westerly, but should it be on the right of the magnetic, it is easterly.

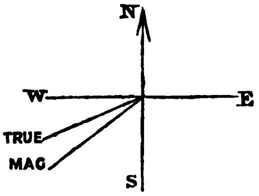
1859,—February 17. At 6^h 48^m app. time at ship, in lat. 34° 57′ N., long. 40° 8′ E.; the sun's magnetic amplitude was W. 22° 30′ S. Required the variation.

	d	h	m	″
App. S. T.	17	6	48	
Long. in time, E. —		2	40	32
App. G. S.	17	4	7	28

Long. 40°	8′	E.
	4	
60)160	32	
2	40	32

					″
⊙'s dec. S.	12°	3′	23″	—	52.63
		3	36		4.1
	11	59	47		5263
					21052
					60)215.783
					3 36

Sin.	12°	0′	=		9.317879
Sec.	34	57	=		086370
True amp. W.	14°	42′	S. =	Sin.	9·404249
Mag. amp. W.	22	30	S.		
Var.	7	48	E.		



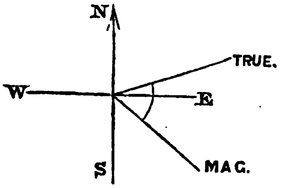
1859. March 29th. At 5^h 50^m app. time at ship, in lat. 25° 50′ S., long. 127° 35′ W.; the sun's magnetic amplitude was E. 18° 45′ S. Required the variation.

	d	h	m	″
A. S. T.	28	17	50	
Long. in time W. +		8	30	20
A. G. T.	29	2	20	20

	°	′
Long.	127	35 W.
		4
60)510		20
	8	30 20

	°	′	″	″
⊙ Dec. N.	3	17	10	+ 58.37
	+	2	14	2.3
	3	19	24	17511
				11674
				60)134.251
				2.14

	°	′		
Sin.	3	19	=	8.762337
Sec.	25	50	=	045726
True Amp. E.	3	41 N.	=	Sin. 8.808063
Mag. Amp. E.	18	45 S.		
Var.	22	26 W.		



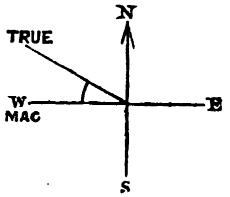
1859. April 5th. At 6^h 15^m app. time at ship, in lat. 20° 20′ S. long. 155° 30′ E; the sun's magnetic amplitude was West. Required the variation.

	d	h	m
A. S. T.	5	6	15
Long. in time E	—	10	22
G. A. T.	4	19	53

	°	′
Long.	155	30 E.
		4
60)622		00
	10	22

	°	′	″	″
⊙ Dec. N.	5	36	7	+ 57 12
		18	57	19.9
	5	55	4	51408
				51408
				5712
				60)1136.688
				18.57

	°	′		
Sin.	5	55	=	9.013182
Sec.	20	20	=	0.027942
	°	′		9.041124
True Amp. W.	6	19 N.		
Mag Amp.	0	0		
Var.	6	19 E.		



EXAMPLES FOR EXERCISE.

(1.) 1859. May 12th, at $4^h\ 22^m$ app. time at ship, in lat. 51° 29′ N., long. 6° 20′ W., the Sun's magnetic amplitude was E. 35° 30′ N. Required the variation.

(2.) ... June 18th, at $4^h\ 54^m$ app. time at ship, in lat 33° 15′ S., long 0° 0′, the Sun's magnetic amplitude was E. 18° 35′ N. Required the variation.

(3.) ... July 20th, at $7^h\ 0^m$ app. time at ship, in lat. 34° 51′ S., long. 172° 28′ E., the Sun's magnetic amplitude was W. 15° 35′ N. Required the variation.

(4.) ... Aug. 6th, at $7^h\ 50^m$ app. time at ship, in lat. 56° 7′ N., long. 2° 30′ W., the Sun's magnetic amplitude was W. 44° 30′ N. Required the variation.

(5.) ... Sept. 23d, at $5^h\ 55^m$ app. time at ship, in lat. 52° 36′ N., long. 125° 10′ W., the Sun's magnetic amplitude was E. 16° 45′ S. Required the variation.

(6.) ... Oct. 11th, at $6^h\ 21^m$ app. time at ship, in lat. 28° 45′ N., long. 23° 25′ W., the Sun's magnetic amplitude was W. 14° 25′ N. Required the variation.

(7.) ... Nov. 10th, at $6^h\ 29^m$ app. time at ship, in lat. 32° 40′ S., long. 15° 10′ E., the Sun's magnetic amplitude was E. 10° S. Required the variation.

(8.) ... Dec. 8th, at $3^h\ 50^m$ app. time at ship, in lat. 17° 56′ N., long. 115° 50′ E., the Sun's magnetic amplitude was W. 47° 50′ S. Required the variation.

LONGITUDE BY CHRONOMETER.

REMARKS.—(1.) To the time by chronometer, apply its original error, adding if slow, subtracting if fast.

(2.) Find the accumulated rate during the interval, by multiplying the number of days elapsed by the daily gain or loss.

(3.) If the chronometer has been losing, add this correction, otherwise subtract it to (1). The time so found is the true mean Greenwich time at the time of observation.

(4.) Take out the sun's dec. and equation of time from page II. of the Naut. Alm.

(5.) Correct each for the Green. time by its own hourly diff.

(6.) If the lat. and dec. are both N. or both S., subtract the dec. from 90°; if one is N. and the other S., add 90° to the dec., the result in either case is the polar distance.

(7.) Note whether the equation of time is to be added to or subtracted from apparent time.

(8.) Find the Sun's true altitude.

(9.) Add together the alt., lat., and pol. dist.; divide this sum by 2, and from the half sum subtract the alt.

(10.) App. time from noon = log. Sec. Lat. + Log. Cosec. Pol. Dist. + log. Cos. Half-Sum + log. Sin. Rem. — 30.

(11.) If it be A.M. at ship, subtract this time from 24^h, putting the ship's date one day back; but if a P.M. sight, no alteration is to be made, only to prefix the day at ship, which must not be neglected, the result in either case will be the true app. ship time.

(12.) Add or subtract the equation of time as directed in (7).

(13.) The result is the true mean time at ship.

(14.) Under this write the Greenwich time, on no account neglecting to prefix the Greenwich day; the difference between the two times is the longitude in time.

(15.) Turn this into arc, by multiplying by 60 and dividing by 4.

(16.) Greenwich time best, long. West. Greenwich time least, long. East. Though this rule is not strictly grammatical, it will serve our purpose better than any other.

1859. January 2d, A.M. at ship in lat. 49° 10′ S., the obs. alt. $\underline{\odot}$ 55° 50′ 50″, H. E. 18 feet, time by chronometer, $2^d\ 1^h\ 15^m\ 2''$, which was fast for mean noon at Greenwich on December 25th, $0^h\ 34^m\ 31''$, and gaining daily 3.5″, index error + 2′ 40″. Required the longitude.

```
              d h  m  ″
Jan.          2 1 15  2   From Dec. 25. to Jan. 2. is 8 days,
Fast,           0 34 31          which multiplied by 3.5 daily rate,
              ---------                              ----
              2 0 40 31                      gives   28.0 seconds, as the to-
Gain,         —      28                                        tal gain.
              ---------
T. M. G T.,   2 0 40  3
              =========
                                  ″                            m    s          s
⊙ dec. p. ii. S. 22° 57′  2″ — 13.91 Eq. of time, p. ii. 4  12.14  +  1.168
         Cor.    —       10      .7     Cor.             +    .82        .7
                 -----------  ------                     ---------   ------
                 22   56  52   9.737                     4  12.96     .8176
                 90                                      =========
                 -----------                           + App. time.
    Pol. Dist.,  67    3   8
                 ===========
```

	°	′	″
Obs. alt. ⊙	55	50	50
I. E., .	+	2	40
	55	53	30
Dip. .	—	4	4
	55	49	26
Ref. .	—		33
	55	48	53
S. D. .		16	18
	56	05	11
Parallax		+	4
True Alt.	56	5	15

	°	′	″		
Alt.	56	5	15		
Lat.	49	10	0	Sec.	.184515
P. D.	67	3	8	Cosec.	.035806*
	2)172	18	23		
	86	9	12	Cos.	9.826635
Alt.	56	5	15		
Rem.	30	3	57	Sin.	9.699833
					8.746789

	d	h	m	″
XXXI.		1	49	20
		24		
True app. ship time,	1	22	10	40
Eq. time,	+		4	13
True mean ship time,	1	22	14	53
True mean Green. time,	2	0	40	3
Longitude in time,		2	25	10
		60		
	4)145	10		
Long. . . .	36	17	30 W.	

1859. Feb. 22d, P.M. at ship in lat. 23° 17′ 30″ N., the obs. alt. ⊙ 28° 52′ 22″, H. E. 21 feet, time by chron. 21d 21h 47m 0″ which was slow for mean noon at Greenw. on Jan. 10th 0h 5m 20″, and losing daily 5.5″, index error + 2′ 26″. Required the longitude.

	d	h	m	″
Feb.	21	21	47	0
Slow		0	5	20
	21	21	52	20
Loss		+	3	56
T. G. M. T.	21	21	56	16

From Jan. 10th to Feb. 21st is an interval of 42 days; in addition to this we have 21h 52m which must not be neglected. Dividing the minutes by 6, as usual, we have 21.9, this is now to be divided by 24; 24 hours making a day, this quotient is .9 of a day nearly. Consequently 42.9 days have elapsed, which multiplied by 5.5 the daily loss, give

2145
2145
60)235.95
3.56 as the total loss.

---

* Log. cosec. of 67° 3′ = .035813 diff. 89
— 7 .8
.035806 712 Divide by 100, or cut off two figures from the right, and subtract the remainder in the log. co-sec, co-sin, or co-tan, but add to the log. sin., &c.

⊙ Dec. S.	10° 38′ 19
Cor.	— 19 51
	10 18 28
	90
P. D.	100 18 28

— 54.38″
21.9
48942
5438
10876
60)1190.922
19.51

Eq. Time	13m 54.35	— .313s
Cor.	— 6 85	21.9
	13 47 50	2817
		313
+ A. Time		626
		6.8547

	° ′ ″
Obs. alt. $\underline{\odot}$	28 4222
I. E. .	+ 2 26
	28 54 48
Dip. .	— 4 23
	28 50 25
Ref. .	— 1 43
	28 48 42
S. D. .	+ 16 12
	29 04 54
Parallax,	+ 8
	29 5 2

		°	′	″		
Alt.		29	5	2		
Lat.		23	17	30	Sec.	036929
P. D.		100	18	28	Cosec.	.007067*
	2)152		41	00		
		76	20	30	Cos.	9.373154
Alt.		29	5	2		
		47	15	28	Sin.	9.865951
	d	h	m			9.283101
T. A. S. T.	22	3	27	51		28304
Eq. Time		+	13	48		s
						6 = 1
T. M. S. T.	22	3	41	39		
T. M. G. T.	21	21	56	16		
Long. in time		5	45	23		
		60				
	4)345		23			
Long.		86°	20′	45″ E.		

1859. March 14th, A.M. at ship in lat. 32° 12′ 40″ N., the obs. alt. $\overline{\odot}$ 29° 11′ 45″ H. E. 12 feet, time by chron. 13d 17h 45m 26″, which was fast for mean noon at Greenwich on Jan. 26th 1h 41m 37″, and gaining daily 7·5″, ind. error, —9′ 27″. Required the long.

	d	h	m	″			
	13	17	45	26	Jan.	5 days	16 hours reduced to the decimal of a day = $\frac{16}{24}$ =.7 nearly.
Fast, .		1	41	37	Feb.	28 ...	
					March	13 ...	
	13	16	3	49		46·7	
Gain, .	—		5	50		7·5	
T. M. G. T.,	13	15	57	59		2335	
						3269	
						60)350.25	
						5.50	

---

* When the P. D. exceeds 90°, take out the sec. of the dec.

	° ′ ″	″		m s	
⊙'s dec. S.	3 0 44	— 59.08	Eq. time,	9 45 56	— .698
	15 45	16		— 11 17	16
	2 44 59	35448		9 34 39	4188
	90	5908		+ App. time,	698
P. D.	92 44 59	60)945.28			11.168
		15.45			

	° ′ ″		° ′ ″		
Obs. alt. ⊙	29 11 45	Alt., .	28 41 18		
I. E., .	— 9 27	Lat., .	32 12 40	Sec.,	.072583
		P. D., .	92 44 59	Cosec.	.000500
	29 2 18				
Dip., .	— 3 19		2)153 38 57		
	28 58 59		76 49 29	Cos.	9.357803
Ref., .	— 1 42	Alt., .	28 41 18		
	28 57 17		48 08 11	Sin.	9.872002
S. D., .	— 16 7		d h m ″		9.302888
	28 41 10		3 33 0		
Px., .	+ 8		24		
True alt.	28 41 18	T. A. S. T.,	13 20 27 0		
		Eq. time,	+ 9 34		
		T. M. S. T.,	13 20 36 34		
		T. M. G. T.,	13 15 57 59		
			4 38 35		
			60		
			4)278 35		
		Long.,	69 38 45 E.		

Examples for Exercise.

(1.) 1859.—April 25th, A.M. at ship, in lat. 33° 47′ 20″ S., the obs. alt. ⊙ 28° 34′ 12″, H. E. 10 ft., time by chronometer 24^{d} 16^{h} 0^{m} 38″, which was slow for mean noon at Greenwich on March 29th 0^{h} 30^{m} 28″, and losing daily 4.4″, I. E. — 4′ 10″. Required the longitude.

(2.) ... May 28th, P.M. at ship, in lat. 10° S., ⊙ 28° 49′ 10″, H. E. 13 feet; time by chronometer 28^{d} 11^{h} 32^{m} 11″, slow for Greenwich mean noon on May 10th, 0^{h} 10^{m} 20″, gaining daily 1.4″, I. E. — 2′ 2″. Required the longitude.

(3.) 1859. June 9th, P.M. at ship in lat. 29° 11′ N., $\underline{\odot}$ 28° 57′ 10″, H. E. 25 feet, time by chronometer 8^d 22^h 42^m 20″, fast on April 30th 0^h 4^m 20″, and losing daily 4.5″, I. E. — 0′ 50″. Required the longitude.

(4.) ... July 14th, P.M. at ship in lat. 44° 20′ N., $\underline{\odot}$ 39° 27′ 30″, H. E. 23 feet, time by chronometer 13^d 16^h 56^m 36″, fast on June 27th 1^h 2^m 40″, losing 2.5″, I. E. — 2′ 40″. Required the longitude.

(5.) ... August 23, A.M. at ship in lat. 47° 0′ N., $\underline{\odot}$ 37° 40′ 10″, H. E. 18 feet, time by chronometer 23^d 8^h 40^m 21″, slow June 8th 0^h 13^m 45″, losing daily 1.5″, I. E. — 4′ 0″. Required the longitude.

(6.) ... Sept. 23d, P.M. at ship in lat. 14° 18′ N., $\underline{\odot}$ 19° 20′ 33″; H. E. 20 feet, time by chronometer 23^d 3^h 27^m 26″, fast Sept. 5th 1^h 21^m 30″, gaining 8″ daily, I. E. + 1′ 20″. Required the longitude.

(7.) ... October 25th, A.M. at ship, in lat. 52° 20′ S., $\overline{\odot}$ 17° 22′ 40″, H. E. 20 feet, time by chronometer 25^d 2^h 16^m 49.5″, slow April 12th 1^h 16^m 20″, gaining 2″ daily, I. E. + 2′ 20″. Required the longitude.

(8.) ... Nov. 22d, A.M. at ship in lat. 51° 20′ S., $\underline{\odot}$ 39° 22′ 45″, H. E. 23 feet, time by chronometer 21^d 19^h 10^m 29″, slow Nov. 11th 1^h 14^m 20″, gaining daily 3.5″, I. E. + 1′ 15″. Required the longitude.

(9.) ... Dec. 14th, P.M. at ship in lat. 46° 50′ S., $\overline{\odot}$ 40° 38′ 40″, H. E. 20 feet, time by chronometer 13^d 21^h 25^m 40″, slow on December 5th 1^h 29^m 30″, gaining daily 10″, I. E. + 2′ 35″. Required the longitude.

At some of the ports the chronometer is proposed in this form—

1859, Jan. 2d, at 10^h 20^m A.M., mean time at place nearly, in lat. 49° 10′ S., long. by acct. 36° W., time by chronometer 1^h 15^m 2″, which was fast for Greenwich mean noon on December 25th, 0^h 34^m 31″, and gaining daily 3.5″, I. E. + 2′ 40″. Required the longitude.

When given as above, we have to determine for ourselves the Green. day—that is, if the time as shewn by the chronometer was 1^h, &c, on the civil or on the astronomical day, because if it should prove to be 1^h of the civil day, we must refer it to the astronomical, by adding 12 hours to the chronometer time and throwing off one day. To determine this point :—

	d	h	m	
Astron. date at ship nearly Jan. 1st		22	20	Long. 36° W.
Long. by account in time W.,	+	2	24	4
				60)144
Astron. Greenwh. time nearly	2	0	44	2 24

Now, as the Greenwich time nearly is about 1 hour from noon, it proves that the chronometer must have shewn 1 hour from noon also, and therefore we proceed as usual.

	d	h	m	″		
T. by C.	2	1	15	2	Interval,	8″
Fast, . .		0	34	31		5.5
		0	40	31		28.0
Gain, . .				28		
T. G. M. T.,	2	0	40	3	and so on with the rest of the work.	

Feb. 22d, at 3^h 40^m P.M. mean time at ship nearly ; in lat. 23° 17′ 30″ N., and long. by acct. 86° 20′ E., the obs. alt. ☉ 28° 52′ 22″, H. E. 21 feet, time by chronometer 9^h 47^m 0″ which was slow for G. M. noon on January 10th, 0^h 5^m 20″, and losing daily 5.5″, I. E. + 2′ 26″. Required the longitude.

	d	h	m	
Mean time at ship nearly	22	3	40	Long. by acct. 86° 20′ E.
Long. by acct. in time E.		5	45	4
M. G. T. nearly	21	21	55	345 20
				5 45 20

Consequently the time as shewn by the chronometer was 21^h 47^m on the 21st day.

March 14th, at 8^h 30^m A.M. mean time at ship nearly; in long. by acct. 69° 40′ E., time by chronometer 5^h 45^m 26° fast 1^h 41^m 37″, &c., &c.

	d h m	
Astr. T. at ship nearly	13 20 30	Long. 69° 40′ E.
Long. in time E.	— 4 39	4
	13 15 51	278 40
		4 38 40

	d h m ″
Therefore, time by chronometer was	13 17 45 26
Fast	1 41 37
	16 3 49

ADDITIONAL FOR FIRST MATE.

To find the Variation of the Compass by Azimuth.

REMARKS.—(1.) If an A.M. sight, add 12 hours, and throw off one day from the date at ship; if a P.M., no alteration is to be made.

(2.) Apply the long. in time and find the Greenwich time.

(3.) Take out the Sun's dec. from page 2, N. A.; correct it and find the polar dist.

(4.) Obtain the true alt.

(5.) Add together the P. D., alt., and lat.; divide the sum by 2, and take the difference between the half sum and the P.D., which is called the remainder.

(6.) Add together the

Log. sec. of alt. } rejecting 10 from the
... sec. of lat. } index of each.
... cos. of half sum.
... cos. of rem.

(7.) Half the sum of these logs. will be the log. sin. ot half the true azimuth.

(8.) Multiply by 2, and the product is the true az., reckoned from the N. in South lat., and from the S. in North lat., and towards the E. or W. according as to whether it be an A.M. or P.M. observation.

(9.) The diff. between the true az. and mag. az. will be the var. which is E. or W., according to the rule laid down in the amplitude.

(10.) If the true and mag. bearings should be of contrary names, take one of them from 180°, and proceed as in (9).

1859. Jany. 22d, at 10^h 14^m A.M., mean time at ship in lat. 39° 15′ S., long. 96° 20′ E., the Sun's magnetic bearing N. 92° 30′ E., the obs. alt. $\overline{\odot}$ 46° 9′ 30″, H. E. 19 ft., I. E. + 2′ 10″. Required the Variation.

	d	h	m
M. T. at ship	21	22	14
Long. in time E.		— 6	25
M. G. time	21	15	49

	°	′	
Long.	96	20	E.
		4	
	385	20	
	6	25	20

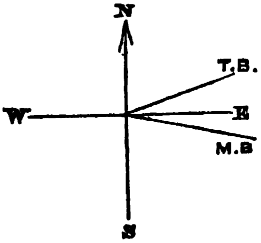
	°	′	″
$\odot$ Dec.	19	57	23
		— 8	53
	19	48	29
	90		
P. D.	70	11	31

″
— 33.73
15.8
26984
16865
3373
532.934
8 53

		°	′	″
Obs alt. $\overline{\odot}$		46	9	30
I. E.	.	+	2	10
		46	11	40
Dip	.		4	11
		46	7	29
Ref.	.	—		55
		47	6	34
S. D.	.		16	17
		46	50	17
Px.	.		+	6
True alt.		46	50	23

	°	′	″		
P. D.	70	11	31		
Alt.	46	50	23	Sec.	.164866
Lat.	39	15	0	Sec.	.111039
	2)156	16	54		
	78	8	27	Cos.	9.313097
P. D,	70	11	31		
Rem.	7	56	56	Cos.	9.995806
					2)19.584808

	°	′			
½-True Az.	38	19		Sin.	9.792404
		2			
True Az. N.	76	38	E.		
Mag. Az. N.	92	30	E.		
Var.	15	52	W.		



Westerly var., the true bearing being to the left of the mag.

Feb. 24th, at 2^h 45^m P.M. mean time at ship, in lat. 5° N. and long. 165° E, the Sun's magnetic bearing N., 140° 15′ W., obs. alt ☉ 60° 39′ 5,″ H. E. 19 feet, I. E. — 2′ 6″. Req. the var.

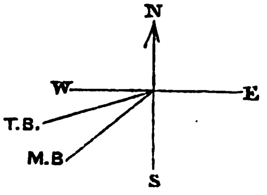
	d h m
M. time at ship	24 2 45
Long. in time E.	— 11 0
M. G. time	23 15 45

Long. 165° E.
4
60)660
11 0

	° ′ ″	″
☉ Dec. S.	9 54 39	— 55.15
	— 14 28	15.8
	9 40 11	41120
	90	27575
		5515
P. D.	99 40 11	
		60)868.370
		14.28

	° ′ ″
Obs. alt. ☉	60 39 5
I. E. .	— 2 6
	60 36 59
Dip .	— 4 11
	60 32 48
Ref. .	— 32
	60 32 16
S. D. .	+ 16 12
	60 48 28
Parallax .	+ 4
Tr. alt. .	60 48 32

		° ′ ″		
P. D.		99 40 11		
Alt.		60 48 32	Sec.	.311931
Lat.		5 0 0	Sec.	001656
		2)163 28 43		
		82 44 22	Cos.	9.102048
P. D.		99 40 11		
Rem.		6 55 49	Cos.	9.996812
				2)19.412447
			Sin.	9.706223
		′ ″		
½-true Az.		30 34		
		2		
True Az.	S.	61 8	W.	
		180 0		
...	N.	118 52	W.	
Mag. Az.	N.	140 15	W.	
Var.		21 23	E.	



Examples for Exercise.

(1.) 1859. March 23d, at 10^{h} 20′ A.M. mean time at ship, in lat. 36° 29′ N., long. 139° 15′ W., the Sun's magnetic bearing was S. 52° 40′ E., obs. alt. $\underline{\odot}$ 46° 47′ 10″, H. E. 19 feet. ; I. E. + 2′ 15″. Required the variation.

(2.) April 19th, at 2^{h} 50^{m} P.M. M. T. at ship in lat. 13° 30′ S., long. 98° 20′ E., the Sun's mag. bearing was S. 100° 25′ W., obs. alt. $\underline{\odot}$ 40° 34′ 00″, H. E. 17 feet, I. E. + 1′ 25″ —.

(3.) May 26th, at 10^{h} 13m A.M. M. T. at ship, in lat. 31° 56′ N., long. 150° 30′ W., the Sun's mag. bearing was N. 121° 30′ E., obs. alt $\overline{\odot}$ 63° 45′ 45″, H. E. 18 feet, I. E. — 2′ 20″. Required the variation.

(4.) June 12th, at 8^{h} 20^{m} A.M M. T. at ship, in lat. 20° 10′ N., long 29° 33′ W., the Sun's mag. bearing S. 80° 25′ W., obs. alt. $\underline{\odot}$ 39° 34′ 40″, H. E. 23 feet, I. E. — 2′ 10″. Required the variation.

(5.) July 22d, at 3^{h} 50^{m} P.M. M. T. at ship, in lat. 10° 10′ S., long. 60° 50′ E., the Sun's mag. bearing N. 20° 15′ W., obs. alt. $\underline{\odot}$ 49° 32′ 30″, H. E. 23 feet, I. E. + 2′ 10″. Required the variation.

(6.) Aug. 28th, at 3^{h} 14^{m} P.M. M. T. at ship, in lat. 38° 46′ N., long. 97° 50′ E., the Sun's mag. bearing S. 68° 10′ W., obs. alt. $\underline{\odot}$ 26° 54′ 30″, H. E. 17 feet, I. E. + 2′ 45″. Required the variation.

(7.) Sept. 17th, at 9^{h} 28^{m} A.M. M. T. at ship, in lat. 40° 12′ N., long. 114° 35′ E., the Sun's mag. bearing N. 100° 35′ E., obs. alt. $\underline{\odot}$ 27° 2′ 00″, H. E. 25 feet, I. E, + 4′ 40″. Required the variation.

(8.) October 12th, at 3^{h} 30^{m} P.M., in lat 42° 10′ N., long. 144° 15′ E., the Sun's mag. bearing S. 45° 40′ W., obs. alt. $\underline{\odot}$ 20° 32′ 46″ ; H. E. 21 feet ; I. E. + 4′ 27″. Required the variation.

(9.) Nov. 23d, at 3^{h} 14^{m} P.M M. T.. at ship, in lat. 20° 30′ N., long. 36° 30′ W., the Sun's mag. bearing S. 72° 30′ W., obs. alt. $\underline{\odot}$ 14° 39′ 50″, H. E. 20 feet, I. E. + 2′ 15″. Required the variation.

(10.) Dec. 21st, at 3^{h} 10^{m} P.M. M. T. at ship, in lat. 20° 9′ N., long. 111° 13′ W., the Sun's mag. bearing S. 60° 20′ W., obs. alt. $\underline{\odot}$ 25° 53′ 10″, H. E. 22 feet, I. E. + 4′ 10″. Required the variation.

To find the Latitude by Reduction to the Meridian.

Remarks.—(1.) This observation is made either before or after the Sun is on the meridian of the ship, and is a most useful problem in cloudy weather, when, as it sometimes happens, the Sun is obscured at noon.

(2.) To the time by watch apply its error, adding if slow, but subtracting if fast.

(3.) If the ship has made *Westing* since the error was determined, turn the difference of longitude into time and subtract; if she has made *Easting*, add.

(4.) The result is the true apparent ship time, which, if P.M., is the *apparent time from noon or hour angle.*

(5.) If the true apparent ship time is A.M., take it from 24 hours, and the difference is the hour angle.

(6.) To the true apparent ship time apply the longitude in time as usual; the result is the true apparent Green. time.

(7.) Take the Sun's declination from page 1, N. A., and correct it for G. T.

(8.) Correct the Sun's altitude.

(9. Add together—

Log. rising of the time from noon or H. A. (Table XXIX).
Log. cos. of the lat. by acct., ... (... XXV).
Log. cos. of the Sun's declin., ... (... XXV).

(10.) From this sum reject 20 in the index, and find the corresponding Nat. number from Table XXIV.

(11.) Add this number to the Nat. sine of the true altitude (XXVI.), using *five* figures only.

(12.) Find the Nat. cosine corresponding to this sum, which will be the meridian zenith distance N. or S., according as the Sun's bearing is S. or N.

(13.) Add or subtract the declination according to its name.

(14.) The result is the latitude of the ship's position.

1859. January 7th, P.M. at ship in lat. by acct. 56° 10′ S., long. 67° 3′ E., the obs. alt. $\underline{\odot}$ north of observer was 56° 2′ 50″, H. E. 22 feet, time by watch $11^h\,22^m\,32''$ which had been found to be slow of app. time at ship $0^h\,56^m\,17''$, the diff. of long. made to the east since the error was determined was 12′, index error + 0′ 16″. Required the latitude.

	d	h	m	″	
Astron. time by watch, Jan.	6	23	22	32	Run, 12′ E.
low	0	0	56	17	4
	7	0	18	49	48 seconds.
Run E.	+			48	
True app. ship time,	7	0	19	37	also hour angle.
Long. 67° 3′ E. in time.		4	28	12	
4					
	6	19	51	25	true app. Greenwich time.
268 12					
4 28 12					

	°	′	″		″		°	′	″
⊙'s dec. p. 1., S.	22	32	2	—	18.42	Obs. alt. ⊙	56	2	50
	—	6	6		19.9	I. E., .	+		16
	22	25	56		16578		56	3	06
					16578	Dip, .	—	4	30
					1842				
							55	58	36
					366558	Ref., .		—	38
					6.6		55	57	58
						S. D., .		16	18
							56	14	16
						Px., .		+	5
						True alt.,	56	14	21

			168		
Hour angle,	$0^h\ 19^m\ 37''$	Rising,	2.56211	Table	XXIX.
Lat by acct.,	56° 10′	Cos.,	9.74568	...	XXV.
Sun's dec.	22° 56′	Cos.,	9.96424	...	XXV.

Table XXIV., Nat. number 188 = 2.27371
Nat. Sine 56° 14′ = 83131 (XXVI.)

Nat. cos., 83319 = 33° 34′ S. Mer. zenith dist.
Dec., 22° 56′ S.

Lat. in 56° 30′ S.

1859. Feb. 4th, A.M. at ship, in lat. by acct., 19° 55′ N., long. 25° 30′ W., the obs. alt. ⊙ south of obs. was 53° 18′ 15″, H. E. 16 feet, time by watch $2^h\ 5^m\ 32''$, which was fast of app. time at ship $2^h\ 30^m\ 10''$, the diff. of long. made to the east since the error was determined was 27′ I. E. — 1′ 15″. Required the latitude.

	d	h	m	″		d	h	m	″		°	′
Time by Watch	4	2	5	32	T. Ap. S. T.	3	23	37	10	Long.	25	30 W.
Fast		2	30	10	Long. in T. W.	+1	42	0				4
Ap. T. at ship nearly.	3	23	35	22	T. A. G. T.	4	1	19	10		60)102	00
Run to the E. in T. = $\frac{27'\times 4}{60}$ =			+1	48							1	42
True Ap. Ship Time	3	23	37	10								
		24										
Time from noon or H. A.			22	50								

	h	m	″		″
⊙ Dec. S.	16	17	16	—	45.12
	—		59		1.3
	16	16	17		13536
					4512
					58.656

	″	′	″
Ob. alt ⊙	53	18	15
I. E. .	—	1	15
	53	17	00
Dip. .	—	3	50
	53	13	10
Ref. .	—		43
	53	12	27
S. D. .	+	16	15
	53	28	42
Px. .			5
True alt.	53	28	47

	h	m	″		
Time from noon	0	22	50	Rising	2.69538
Lat. by acct. ,		19	55	Cos.	9.97322
Dec. . .		16	16	Cos.	9.98226
			448	=	2.65086
Nat. sine 53° 29′ =			80368		

		°	′	
Nat. Cos.	80816 =	36	5	N. Mer. Z. D.
	Dec.	16	16	S.
	Lat.	19	49	N.

1859. March 16th A.M. at ship in lat. by acct. 37° 50′ N. long. 61° 40′ E., the obs. alt. ⊙ south of obs., was 50° 0′ 30″. H. E. 15 feet, time by watch, 10^h 53^m 31″, which was slow of app. time at ship, 1^h 3^m 22″, the diff. of long. made to th″ west since the error was determined was 18′, I. E. + 0′ 34. Req. the lat.

	d	h	m	″
Astron. T by watch	15	22	53	31
Slow		1	3	22
A. T. at ship nearly	15	23	56	53
Run to the W. in T. = $\frac{18'\times 4}{60}$ =		—	1	12
T. App. T. at ship	15	23	55	41
		24		
Time from noon			4	19

	d	h	m	″
T. A. T. at S.	15	23	55	41
Long. time E.	—	4	6	40
T. A. Gr. T.	15	19	49	1

	°	′
Long.	61	40 E.
		4
60)	246	40
		4 640

	° ′ ″		″		° ′ ″
Sun's dec. S.	2 13 27	—	59.18	Obs alt. ⊙	50 0 30
Cor. —	19 32		19.8	I. E. .	+ 0 34
T. Dec.	1 53 55		47344		59 1 04
			53262	Dip. .	— 3 42
			5918		
					49 57 22
			60)1171.764	Ref. .	— 48
			19.32		49 56 34
				S D. .	+ 16 6
					50 12 40
				Px. .	+ 6
				T. alt.	50 12 46

	h m ″		
Time from noon .	0 4 19	Rising	1.25224
Lat. by acct. .	37 50	Cos.	9.89752
Dec. .	1 54	Cos.	9.99976
Nat. no.	14	=	1.14952
Nat. sine 50° 13″ =	76847		

Nat. Cos. 76861 = 39° 46′ N. M. L. D.
Dec. 1 54 S.
Lat. 37 52 N.

Examples for Exercise.

(1.) 1859.—April 2d, A.M. at ship in lat. by acct. 41° 40′ S., long. 126° 45 W., the obs. alt. ⊙ N. of obs. was 42° 26′ 30″, H. E. 17 feet, time by watch 3^h 36^m 20″, which was fast of app. T. at ship 4^h 9^m 38″, the diff. of long. made to the West since the error was determined was 25′, I. E. — 1′ 40″. Required the latitude.

(2.) ... May 6th, A.M. at ship in lat. by acct., 51 S., long. 85° W., the obs. alt. ⊙ N. of obs. was 21° 51′ 40″, H. E. 17 feet, time by watch 11^h 31^m 21″, which was slow of App. T. at S. 0^h 10^m 6″, the diff. of long. made to the East since the error was determined was 14′, I. E. + 8′ 10″. Required the latitude.

(3.) ... June 28th, P.M. at ship in lat. by acct. 27° 24′ S., long. 75° 30′ E., the obs. alt. ⊙ N. of obs. was 38° 30′ 0″, H. E. 15 feet, time by watch 0^h 29^m 11″, which was fast of A. S. time 0^h 1^m 12″, the diff. of long. made to the East since the error was determined was 9′, I. E. 0′ 0″. Required the latitude.

(4.) 1859.—July 3d, A.M. at ship in lat. by acct. 26° 20′ S., long. 166° 15′ W., the obs. alt. $\underline{\odot}$ N. of obs. was 40° 30′ 10″, H. E. 20 feet, time by watch 11^{h} 48^{m} 40″, which was fast of A. S. T. 0^{h} 7^{m} 30″, the diff. of long. made to the East since the error was determined was 28′, I. E. + 1′ 20″. Required the latitude.

(5.) ... Aug. 24th, A.M. at ship in lat. by acct. 53° 30′ N., long. 20° 17′ W., the obs. alt. $\underline{\odot}$ S. of obs. was 47° 11′ 15″, H. E. 21 feet, time by watch 2^{h} 17^{m} 14″, which was fast of A. S. T. 2^{h} 30^{m} 27″, the diff. of long. made to the West since the error was determined was 17′, I. E. + 3′ 11″. Required the latitude.

(6.) ... Sept. 12th, P.M. at ship in lat. by acct. 37° 38′ N., long. 150° E., the obs alt. $\underline{\odot}$ S. of obs. was 55° 38′ 20″, H. E. 13 feet, time by watch 10^{h} 5^{m} 33″, which was slow of A. S. T. 2^{h} 26^{m} 20″, the diff. of long. made to the East since the error was determined was 8′, I. E. — 0′ 55″. Required the latitude.

(7.) ... Oct. 29, P.M. at ship in lat. by acct. 28° 25′ N., long. 162° 35′ W., the obs. alt. $\underline{\odot}$ S. of obs. was 47° 52′ 20″, H. E. 14 feet, time by watch 1^{h} 13^{m} 12″, which was fast of A. S. T. 0^{h} 58^{m} 3″, the diff. of long. made to the West since the error was determined was 21′, I. E. + 1′ 10″. Required the latitude.

(8.) ... Nov. 10th, P.M. at ship in lat. by acct. 60° 12′ N., long. 32 30 E., the obs. alt. $\underline{\odot}$ S. of obs was 11° 48′ 45″, H. E. 18 feet, time by watch 0^{h} 56^{m} 12″, which was fast of A. S. T. 0^{h} 4^{m} 18″, the diff. of long. made to the West since the error was determined was 24′, I. E. 0° 0′. Required the latitude.

(9.) ... Dec. 23d, P.M. at ship in lat. by acct. 42° 10′ N., long. 4° 30′ W., the obs. alt. $\underline{\odot}$ S. of obs. was 23° 45′ 30″, H.E. 11 feet, time by watch 12^{h} 40^{m} 58″, which was fast of A. S. T. 0^{h} 9^{m} 36″, the diff. of long. made to the East since the error was determined was 22′, I. E. — 3′ 20″. Required the latitude.

ADDITIONAL FOR ORDINARY MASTERS.

To find the Latitude by the Meridian Altitude of a Fixed Star.

Remarks.—(1.) Correct the obs. alt. for Index error, Dip, and Refraction.

(2.) Subtract the true alt. from 90°.

(3.) To the mer. zenith dist. apply the star's dec., obtained from pp. 360, 361, and 362 of the N. A.

(4.) The result is the latitude.

1859. The obs. mer. alt. of Scorpii bearing south was 43° 18′ 50″, H. E. 12 feet, I. E. + 1′ 20″. Req. the lat.

		°	′	″	
Obs. alt.	.	43	18	50	
I.E. .	.	+	1	20	
		43	20	10	
Dip .	.	—	3	19	
		43	16	51	
Ref. .	.	—	1	1	
True alt.	.	43	15	50	
		90			
M. Z. D.	.	46	44	10	N.
*'s Dec.	.	26	6	55	S. (page 361.)
Lat.		20	37	15	N.

1859. The obs. mer. alt. of β Geminor. bearing south was 57° 28′ 50″, H. E. 15 feet, I. E. — 2′ 30″. Req. the lat.

		°	′	″	
Obs. alt.	.	57	28	50	
I. E. .	.	—	2	30	
		57	26	20	
Dip ,	.	—	3	42	
		57	22	38	
Ref. .	.	—		37	
True alt.	.	57	22	1	
		90			
M. Z. D.	.	32	37	59	N.
*'s Dec.	.	28	21	47	N. (page 360.)
Lat.		60	59	46	N.

1859. The obs. mer. alt. of Regulus bearing north was 44° 12′ 20″, H. E. 13 feet, I. E. — 2′ 30″. Req. the lat.

	°	′	″	
Obs. alt. .	44	12	20	
I. E. . .	—	2	30	
	44	9	50	
Dip . .	—	3	27	
	44	6	23	
Ref. . .	—	0	59	
True alt. .	44	5	24	
	90			
M. Z. D. .	45	54	36	S.
*'s Dec. .	12	39	17	N. (page 361.)
Lat.	33	15	19	S.

EXAMPLES FOR EXERCISE.

1859. The obs. mer. alt. of α Cassiopea bearing north was 62° 24′ 50″. H. E. 19 feet, I. E. — 7′ 30″. Req. the lat.

(2.) The obs. mer. alt. of Canopus bearing south was 62° 27′ 40″, H. E. 21 feet, I. E. + 3′ 20″. Req. the lat.

(3.) The obs. mer. alt. of α Aurigæ bearing north was 20° 17′ 45″, H. E. 13 feet, I. E. + 0′ 45″. Req. the lat.

(4) The obs. mer. alt. of α Bootis bearing south was 64° 18′ 10″, H. E. 20 feet, I. E. + 2′ 15′. Req. the lat.

(5.) The obs. mer. alt. of Procyon bearing south was 46° 29′ 50″, H. E. 11 feet, I. E. + 2′ 55″. Req. the lat.

(6.) The obs. mer. alt. of α Pegasi bearing north was 47° 16′ 30″, H. E. 20 feet, I. E. + 3′ 50″. Req. the lat.

LOCAL DEVIATION.

The iron used in the construction and equipment of ships exerts an influence on the compass needle, in deflecting it right or left of the magnetic meridian. This deflection is called the Local Deviation, and is found to change when the direction of the ship's head is changed. The following method for finding its amount is copied from Commander Walker's admirable work "On the Magnetism of Ships, and the Mariner's Compass," a book which we earnestly recommend to all seamen.

"Whenever a ship anchors in a place where some fixed object is easily seen at a distance of eight or ten miles, its compass bearing should be noted, as well as the direction of the ship's head. Write down the points of the compass on a slate, and as the ship swings by wind or tide from one point to another, write down the compass bearing of the distant object, opposite to the direction of the ship's head. If the compass be in error, the bearings of the distant object will vary, as the ship swings from point to point, and their difference will ultimately give the amount of deviation. As the ship swings round, there will be two nearly opposite points of the compass on which the bearings of the distant object agree; and this *should* be the correct magnetic bearing of the object, and the points on which there is no compass error. Two other points will be found, in a table so filled up—and nearly opposite points—where the bearings of the distant object greatly differ; *half their difference* will be the deviation on these points, and it will be easily seen if easterly or westerly." If easterly allow to the right, and if westerly to the left.

Direction of Ship's Head.	Deviation of Compass.	Direction of Ship's Head.	Deviation of Compass.
	° ′		° ′
N.	0 22 W.	S.	0 16 E.
N. *b.* E.	1 46 E.	S. *b.* W.	1 50 W.
N. N. E.	3 20 E.	S. S. W.	3 16 W.
N. E. *b.* N.	5 14 E.	S. W. *b.* S.	4 48 W.
N. E.	7 14 E.	S. W.	6 16 W.
N. E. *b.* E.	8 54 E.	S. W. *b.* W.	7 40 W.
E. N. E.	10 44 E.	W. S. W.	9 18 W.
E. *b.* N.	11 40 E.	W. *b.* S.	10 34 W.
E.	10 44 E.	W.	11 50 W.
E. *b.* S.	9 54 E.	W. *b.* N.	11 10 W.
E. S. E.	9 8 E.	W. N. W.	10 16 W.
S. E. *b.* E.	7 20 E.	N. W. *b.* W.	9 18 W.
S. E.	6 18 E.	N. W.	7 52 W.
S. E. *b.* S.	5 0 E.	N. W. *b.* N.	6 18 W.
S. S. E.	3 24 E.	N. N. W.	5 2 W.
S. *b.* E.	1 42 E.	N. *b.* W.	3 10 W.

Correct the following Compass Courses for Deviation:—
E. S. E., N. ¼ E., N. ½ W., W. ¾ S., W. N. W. ¼ N.

E. S. E. = 6 pts. *l.* S. = 67° 30′ *l.* S.
Dev., = 9 8 *r.*

Corrected Co. S. 58 22 E.

N. ¼ E. = ¼ pt. *r*. N. = 2° 49′ *r*. N. Dev. at N. = 0° 22′ W.
Dev. = 10 *r*. „ N.*b*.E. = 1 46 E.

Cor. co. N. 2 59 E 4)2 08 change on 1 pt.

32 change on ¼ pt.
Dev. at 0 pt. = 22 W.

10 E. dev. on ¼ pt.

N. ½ W. = ½ pt. *l*. N. = 5° 38′ *l*. N. Dev. at N. = 0° 22′ W.
Dev. = 1 46 *l*. „ N.*b*.W. = 3 10 W.

N. 7 24 W. 2)2 48 change on 1 pt.

1 24 W. do. ½ pt.
Dev. at 0 = 22 W.

1 46 dev. on ½ pt.

W. ¾ S. = 7¼ pts. *r*. S. = 81° 34′ *r*. S. (7 pts.) 10° 34′ W.
Dev. = 10 53 *l*. (8 pts.) 11 50 W.

S. 70 41 W. 4)1 16

Dev. for ¼ pt. = 19
Dev. for 7 pts. = 10 34

Dev. for 7¼ pts. = 10 53 W.

W.N.W. ¼ N. = 5¾ pts. *l*. N. = 64° 41′ *l*. N. (5 pts.) = 9° 18′ W.
Dev. = 10 1 *l*. (6 pts.) = 10 16 W.

N. 74 42 W. 58
3

4)174

43 dev. for ¾ pts.
9 18 dev. for 5 pts.

10 01 W. dev. for 5¾ pt.

EXAMPLES FOR EXERCISE.

Correct the following Compass Courses for Deviation.

(1.) N.N.W. (2.) S. *b*. E. ¼ E. (3.) W. *b*. S. ¾ S. (4.) N.E. *b*. N. (5.) W. *b*. N. ¼ W.

(6.) E.N.E. ½ E. 7.) S.W. *b* W. (8.) N. (9.) W. ½ N. (10.) S. (11.) N. *b*. E. ¼ N. (12.) E. *b*. S. ¼ S.

ADJUSTMENTS OF THE SEXTANT.

1. *The Index Glass must be perpendicular to the plane of the Instrument.*

Move the vernier to the middle of the arc, and glance obliquely into the mirror, then, if the true and reflected arcs appear as one continued portion of a circle, the index glass is in adjustment.

2. *The Horizon Glass must be perpendicular to the plane of the Instrument.*

Bring O on the vernier to coincide with O on the arc, hold the sextant horizontally, and observe whether the direct and reflected horizons are in one line; if so, the glass is perpendicular.

3. *The Index and Horizon Glasses must be parallel to each other when O on the vernier coincides with O on the arc.*

Bring the Index to Zero, and holding the sextant vertically, look through the telescope at the horizon, and if the true and reflected horizons form an unbroken line, the glasses are parallel to each other.

4. *The Axis of the Telescope must be parallel to the plane of the Instrument.*

Screw on the Telescope, and turn the eye-glass until two of the wires are parallel to the plane of the instrument. Take the distance between the sun and moon or moon and star, at least 90° apart; bring them in contact on the lower wire, then by slightly altering the plane of the instrument, see if they remain in contact at the upper wire; if so, the Telescope is in adjustment.

TO FIND THE INDEX ERROR—

Hold the instrument vertically, and measure the sun's diameter both *on* and *off* the arc. This is done by bringing the reflected sun in contact with the true sun on the left of O, and noting the reading, say 33′ 40″. Again unclamp the instrument, and move the vernier towards you, when the reflected sun is nearly on the other side of the true sun, clamp the instrument, and make the contact perfect with the tangent screw. This reading we will suppose to be 31′ 10″. Set the two readings under each other and take their difference

	′	″
on	33	40
off	31	10
2)	2	30

half this difference, is the index error 1 15 to be subtracted, because the *on* reading is greater than the *off*. If you wish to test the accuracy of your observations, add the two readings together and divide by 4, the quotient should be the semi-diameter for that day.

MERCATOR'S CHART.

(1.) The lines running from north to south parallel to each other are the meridians, those on the extreme right and left being graduated.

(2.) The lines running from east to west are parallels of latitude, the top and bottom being graduated.

(3.) To prick off a ship's place on the Chart, the latitude and longitude being given.

Lay the edge of a scale over the parallel of the given latitude; then, with a pair of compasses, take from one of the graduated parallels the difference between the given latitude and that of the meridian whose longitude is nearest to it, apply this distance along the edge of the scale from the place where the meridian measured from cuts the scale in the same direction that the longitude lies from the meridian, and this will give the ship's place.

(4.) To find the Course or Bearing between two places on the Chart.

Lay the edge of a parallel rule over the two places, and slide the ruler until the edge comes to the centre of the nearest compass; the direction of the edge will indicate the course.

If the Chart be a general one, this will be the true course; and if the compass course be required, allow the variation contrary to the usual way, that is, easterly to the left, and westerly to the right.

(5.) To find the distances between two places on the Chart.

Find the middle latitude between the places, and mark it on the graduated meridian. Take half the distance in the compasses, and measure from the mid. latitude above and below, the degrees intercepted between will be the distance nearly.

6. To find the ship's position from cross bearings.

To ensure accuracy, the difference of bearings should be as near eight points as possible. If a magnetic compass is not on the chart, allow the variation in the usual way to obtain the true bearings. Apply the edge of the parallel ruler to the first bearings, as given by the compass on the chart, and slide it until it touches the first headland, from which draw a line in the opposite direction. Proceed in the same manner with the second bearing. Where the two lines intersect each other will be the ship's place.

THE LOG-LINE.

It is the principle of the log-line, that the length of a knot must bear the same proportion to a nautical mile that the the number of seconds which the glass runs does to the number of seconds in an hour. Or, supposing the ship's speed to be uniform, the number of knots, and parts of a knot, which are run out during the time in which the glass runs, will give the number of miles and parts of a mile which the ship sails.

The geographical mile has 6080 feet, but 6000 feet are generally reckoned. To find the length of a knot for a glass running 30 seconds, we have the following proportion :—

Sec. in 1 hour. Feet. Sec.
As 3600 : 6000 :: 30 : the length of a knot.
Cancelling in the first and second terms, we have
36 : 60 :: 30 : x
Dividing first and second terms by 6,
6 : 10 :: 30 :: x

Or 30
10

6)300

Length of knot 50 feet

Hence follows the rule. Add a cipher to the number of seconds run by the glass, and divide by 6 ; the quotient will be the length of a knot.

DEFINITIONS IN ASTRONOMY.

Q. What are great circles?

A. Great circles are those whose planes pass through the centre of the sphere, dividing it into two equal parts.

Q. What are small circles?

A. Small circles are those whose planes do not pass through the centre of the sphere, dividing it into two unequal parts.

Q. What are meridians?

A. Meridians are great circles, passing through the poles; those drawn on the globe are called terrestrial. The plane of the terrestrial meridians extended to the heavens marks on the sphere the celestial meridians.

Q. Where is the zenith and where the nadir of an observer?

A. The zenith is that point of the heavens which is directly over the observer's head; its opposite point, or that under the observer's feet, is called the nadir.

Q. What is the sensible horizon?

A. The sensible horizon is a plane, conceived to touch the earth at the point where the observer is situated.

Q. What is the rational horizon?

A. The rational horizon is a great circle of the heavens whose plane passes through the centre of the earth parallel to the sensible horizon.

Q. What is the prime vertical?

A. The prime vertical is a great circle at right angles to the meridian, passing through the east and west points of the horizon.

Q. What is the equator?

A. The equator is the great circle on the globe, equally distant from both poles.

Q. What is the equinoctial?

A. The equinoctial is the plane of the equator produced to the heavens.

Q. What is the ecliptic?

A. The ecliptic is the great circle which the sun seems to describe in the heavens.

Q. What is the zodiac?

A. The zodiac is a belt of planets extending about 8° on each side of the ecliptic. The ecliptic is divided into twelve signs, or portions of 30° each, called the signs of the zodiac. They are—Aries, the ram; Taurus, the bull; Gemini, the twins; Cancer, the crab; Leo, the lion; Virgo, the virgin; Libra, the balance; Scorpio, the scorpion; Sagittarius, the archer; Capricornus, the goat; Aquarius, the water-bearer; Pisces, the fishes.

Q. What is the obliquity of the ecliptic ?

A. The obliquity of the ecliptic is the angle which the ecliptic makes with the equinoctial, and is about 23° 28′.

Q. What are the equinoctial points Aries and Libra ?

A. The two points in which the ecliptic cuts the equinoctial.

Q. What is the vernal equinox ?

A. It is the first point of Aries, or the sun's position on the 21st of March.

Q. What is the autumnal equinox ?

A. It is the first point of Libra, or the sun's position on the 21st of September.

Q. What happens when the sun is at those points ?

A. The day and night are of equal length over the whole globe.

Q. What are the solstices ?

A. The solstices are those points on the ecliptic, 90° distant from the equinoctial points, and are so called because the sun appears to stand still for about twenty days. The sun enters those points in June and December ; they are the first points of Cancer and Capricorn.

Q. What is the altitude of a celestial object ?

A. The altitude of a celestial object is the arc of a vertical circle passing through the object, intercepted between the object and the horizon.

Q. What is the zenith distance of a celestial object ?

A. The zenith distance is the complement of the altitude, or it is the arc of a vertical circle intercepted between the object and the zenith.

Q. What is the declination of a celestial object ?

A. The declination of a celestial object is the arc of a circle of declination, intercepted between the object and the equinoctial, and is either north or south.

Q. What is the polar distance of a celestial object ?

A. The polar distance is the arc of a celestial meridian intercepted between the object and the pole. When the latitude and declination are of the *same* name, the polar distance is the complement of the declination ; when the latitude and declination are of *different* names, the polar distance is the sum of the declination and 90°.

Q. What is the azimuth of a celestial object ?

A. The azimuth of a celestial object is the angle at the zenith contained between the meridian of the observer and the vertical circle passing through the object.

Q. What is the amplitude of a celestial object ?

A. The amplitude of a celestial object is the arc of the horizon between a celestial object at rising or setting, and the E. or W. points.

Q. What is the latitude of a celestial object?

A. The latitude of a celestial object is the arc of a circle of latitude intercepted between the object and the ecliptic.

Q. What is the longitude of a celestial object?

A. The longitude of a celestial object is the arc of the ecliptic intercepted between the circle of latitude passing through the body and the first point of Aries.

Q. What is the right ascension of a celestial object?

A. The right ascension of a celestial object is the angle at the pole or arc of the equator, contained between the circle passing through the first point of Aries and the circle of declination passing through the object.

Q. What is apparent time?

A. Apparent time is the hour angle or meridian distance of the sun westward of the meridian. When the sun is on the meridian it is apparent moon.

Q. What is mean time?

A. Mean time is the hour angle or the meridian distance of the mean sun westward of the meridian. When the mean sun is on the meridian it is mean moon.

Q. What do you understand by speaking of a mean sun?

A. The mean sun is an imaginary sun, supposed to travel in the equator with the mean velocity of the true sun. "Were the sun to move eastward in the equator, as he now does in the ecliptic, and were the spaces thus passed over each day uniform, then, although the returns to the meridian would be retarded, the intervals would evidently be perfectly uniform. But as the sun neither moves in the equator, nor are the spaces moved over in the ecliptic uniform each day, he does not return after equal intervals of time, and the apparent solar days are of unequal length.

In order to avoid the inconveniences attendant upon these inequalities, the astronomer compensates them by the following hypotheses:—

First, then, when the sun arrives at that point of the ecliptic where he is nearest to the earth, and his progress along the ecliptic most rapid, an imaginary star is supposed to set out with him, and to move along the ecliptic at the average rate at which the sun moves; at first the star will be outrun by the sun, but as his pace relaxes, the star will again overtake him, and they will arrive together at the opposite point from which they set out, or at that point where the sun is furthest from the earth, and the velocity in the ecliptic the least. Again from this point the star will get at first in advance of the sun, but the sun's rate of motion increasing, they arrive together at the point from which they started. If, now, the transits of this supposed star be considered, instead of the transits of the sun, the unequal motion of the sun is corrected.

In the next place, this star in its progress round the ecliptic must pass through the first point of Aries; and at this instant another imaginary body, called the mean sun, is supposed to set out, and travelling in the equator eastward at the same rate as the star, they meet again at the first point of Libra, each having passed through 180° at the same rate; they are also on the same meridian at the solstices.

If, now, the transits of the mean sun be substituted for those of the star itself, both causes of the inequality of the solar day are compensated.

The *mean solar day* is the interval between two *mean noons*, or transits of the *mean sun* over the meridian.

The difference between mean time and apparent time at any instant is called the equation of time."

Q. How many times in the year are the true sun and mean sun on the same meridian at the same instant?

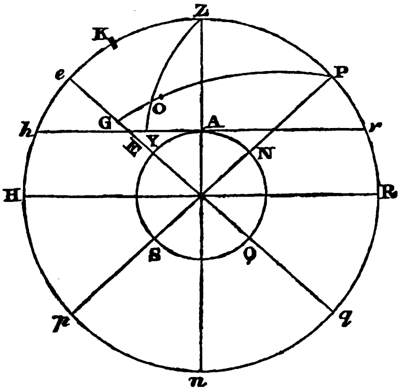
A. Four times; namely, on the 15th of April, 15th of June, 31st of August, and 24th of December. On these days only, the sun, and a clock keeping exact time, coincide.

Q. What is the greatest difference between apparent and mean time?

A. About 16¼ minutes, which happens early in November.

Q What is sidereal time?

A. Sidereal time is the hour angle or meridian distance of Aries westward.



Let the inner circle represent the earth, its circumference being a terrestrial meridian, A the place of a spectator on that meridian. The outer circle represents a celestial meridian, Z being the zenith of the observer.

N and S are the North and South poles of the earth.

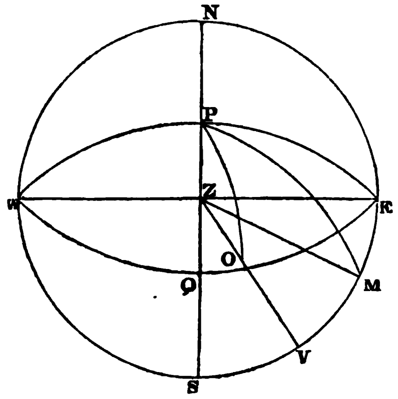
P and p ... ... poles of the heavens.

E Q the equator.
e q the equinoctial.
H R rational horizon,
h r sensible horizon.

If O be a celestial object, O Y is its altitude, Z O its zenith distance. The latitude of a place is its distance from the equator measured on a meridian. Since A is the place of a spectator on the meridian, the arc A E measures his latitude, or the arc Z *e*; for, since every circle is divided into 360°. the inner circle contains as many degrees as the outer, and, therefore, the arc A E of the one, contains as many degrees as the arc Z *e* of the other. To find the latitude by the altitude of a celestial object, we must observe that object when it is on the meridian, say at K; K *h* is its meridian altitude, K *e* its declination north, because the object is N of equinoctial.

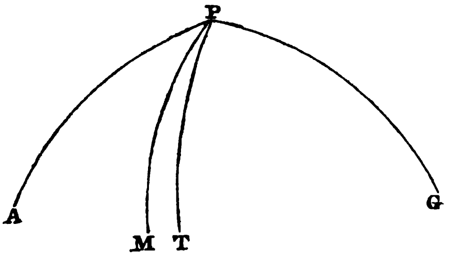
From Z to *h* is 90°; observing K *h*, and subtracting it from 90°, we obtain Z K the meridian zenith distance of the object said to be N, because Z, the zenith of the observer, is north of the object. Adding Z K to K *e*, that is, the zenith distance to the declination, we obtain the number of degrees in the arc Z *e* or the latitude of A.

In this figure, the observer is supposed to be looking perpendicularly from the zenith, from which point the horizon appears as a circle, and the meridians and vertical circles as straight lines.



N W S E the horizon
N Z S the meridian.
P the elevated pole.
Z the zenith
W Z E the prime vertical.
W P E the six o'clock hour circle.

If a celestial object be at O, O V is its altitude, O Z its zenith distance, O P its polar distance, S Z O its azimuth, Z P O its hour angle or meridian distance; if we suppose an object to rise at M, E M is its amplitude.



Let P A be the meridian of the first point of Aries.
P G the meridian of Greenwich.
P M the hour circle of the mean sun.
P T the hour circle of the sun.
Then T P G is apparent time at Greenwich.
M P G is mean time at Greenwich.
A P G is sidereal time at Greenwich.
M P T is the equation of time.
A P M is the right ascension of the mean sun.
A P T is the right ascension of the sun.
A P G is the right ascension of the meridian.

LIST OF THE LEADING LIGHTS IN THE ENGLISH AND BRISTOL CHANNELS.

COAST OF ENGLAND.

North Foreland, on the head, fixed light.
Goodwin Sand.—North sand head light vessel, off N. end of the sand, 3 fixed lights.
———— South sand head light vessel, off S. end of the sand, fixed light.
———— Gull Stream light vessel, near western edge of the sand, 2 fixed lights.
South Foreland, on the head, 2 fixed lights.
Dungeness, extreme point, fixed light.
Beachy Head, upon Belle Toute, a bright revolving light every 2 minutes, duration of flash 15 seconds.
Owers light vessel, E. end of the shoals, fixed light.
Bembridge or Nab light vessel, off the point near the Nab Rock, 2 fixed lights.
Calshot light vessel, off Calshot Castle, revolving light.
Isle of Wight, on the Needles cliff, fixed light.
St Catherine, Isle of Wight, on the point, fixed light.
Portland, near the Bill, 2 fixed lights.
———— on the Breakwater, fixed light.
Start Point, a revolving light seaward; another light in the same tower which is steady.
Eddystone, on the rock, fixed light.
Plymouth, on W. end of Breakwater, fixed red light.
———— W. Barbican Pier-head, fixed light.
Falmouth, St Anthony's Point, revolving light.
Lizard, on the cliff, 2 fixed lights.
Longships, on the rock off Land's end, fixed light.
Seven Stones light vessel, E. side of the rocks, fixed light.
St Agnes', Scilly, summit of the island, revolving light.

COAST OF FRANCE.

Cape Grisnez, on the Cape, revolving light.
Alpreck Point, near the old Semaphore, 2¼ miles S.W. of Boulogne, revolving light.
Ailly, on the Cape, revolving light.
La Hève, on the Cape, fixed light.
Cape Barfleur, new tower on the point, revolving light.

Cape de la Hague, Gros du Raz rock, fixed light.
Caskets, highest of the Casket rocks, 3 revolving lights.
Ushant, N.E. point of island, fixed light.

BRISTOL CHANNEL.

Lundy, on the ridge of the island, upper light revolving, lower light fixed.
Flatholm, on the island, S. point, fixed light.
English and Welsh Grounds light vessel, S. side of Bristol Channel, moored in 6 fathoms, revolving light.
Nash, on the point, fixed light.
Mumbles, on the head, fixed light.
Helwick light vessel, off W. end of the sand, revolving light.
Saundersfoot, on the S. side of Caldy Island, fixed light.
St Ann's, on St Ann's Point, Milford Haven, fixed light.
Smalls, on the rock, fixed light.
South Bishop, on the rock, revolving light.

ANSWERS.

DAY'S WORK.

(1.) N. 7, W. 20.5. N. 7¼, W. 26.6. S. 7¼, E. 30. S. 6¼. E. 10.2. N. 3¾, W. 19.0. S. 1¼, W. 25.5. N. 5, W. 15.1. S. 7¼, W. 20. Lat. in 17° 0′ S. Long. in 20° 5′ W. Course S. 85, W. dist. 57 miles.

(2. S. 2, W. 16. S. ½, E. 24. N. 1¾, W. 25.3. S. 4½, E. 19.3. S. 1¼, W. 23.4. S. 5¼, W. 11.1. S. 3¼, W. 6.3. N. 3¾, W. 23.8. Lat. in 50° 42′ N. Long. in 10° 20′ W. Course S. 37°, W. dist. 54 miles.

(3.) S. 17. S. 6¾, W. 16.6. N. 7¼, W. 17.7. N. 5, W. 8.5: N. 4¼, W. 25.3. S. 7½, W. 19.2. N. 3, W. 20.7. S. 1, W. 21.2. S. 6½, W. 30. Lat. in 10° 1′ N. Long. 74° 25′ E. Course S. 85, W. dist. 124 miles.

(4.) S. 2¾, W. 21. S. 3¼, W. 19.6. S. 5, W. 11.5. S. 1¾, W. 8.5. S. 24.5. S. 3½, E. 15.6. S. 2¾, E. 17. S. 3, E. 19.5. N. 4¼, E. 15.5. Lat. 48° 55′ N. Long. 15° 33′ W. Course S. 3, E. dist. 105 miles.

LOGARITHMS.

(1.) 596.7. (2.) 52026. (3.) 166845.
(4.) 2.494. (5.) 61082816. (6.) 1553.
(7.) 85947843137. (8.) 2210. (9.) 74924.
(10.) .0004370. (11.) 1.647. (12.) 3569827868.

DIVISION.

(1.) 23673. (2.) 1593187. (3.) 1.640.
(4.) 564479. (5.) 342.4. (6.) .0007398.
(7.) 366000. (8.) 51707. (9.) 642.7.
(10.) 73.02. (11.) 1000. (12.) 218.5.

PARALLEL SAILING.

(1.) 170.6 miles. (2.) 612 miles. (3.) 113.8 miles.
(4.) 244.6 miles. (5.) 218.4 miles. (6.) 256.6 miles.

MERIDIAN ALTITUDES.

	° ′ ″		° ′ ″		° ′ ″
(1.)	Lat. 49 14 52 S.	(2.)	48 20 51 N.	(3.)	5 17 11 N.
(4.)	43 14 33 S.	(5.)	45 11 29 N.	(6.)	54 33 51 N.
(7.)	35 3 16 S.	(8.)	35 47 7 N.	(9.)	13 29 34 N.

MERCATOR'S SAILING.

	° ′		° ′
(1.)	S. 25 50 W.—1379 miles.	(2.)	S. 75 11 W.—614 miles.
(3.)	N. 58 30 E.—630.7 miles.	(4.)	N. 19 14 E.—1271 miles.
(5.)	N. 34 0 E.—1212 miles.	(6.)	S. 73 45 E.—1644 miles.
(7.)	N. 85 5 W.—1085 miles.	(8.)	N. 46 45 E.—2731 miles.

TIDES (ABERDEEN).

	h m	h m		h m	h m
(1.)	9 18 P.M.,	8 52 A.M.	(2.)	5 19 P.M.,	4 54 A.M.
(3.)	0 34 P.M.,	0 9 A.M.	(4.)	1 5 P.M.,	0 37 A.M.
(5.)	6 0 P.M.,	5 35 A.M.	(6.)	3 42 P.M.,	3 22 A.M.
(7.)	5 56 P.M.,	5 26 A.M.	(8.)	1 24 P.M.,	0 59 A.M.
(9.)	6 1 P.M.,	5 41 A.M.			

TIDES—*continued.*

	h m	h m		h m	h m
(1.)	9 7 A.M.,	9 38 P.M.	(2.)	2 3 A.M.,	2 22 P.M.
(3.)	3 43 A.M.,	4 6 P.M.	(4.)	10 54 A.M.	11 14 P.M.
(5.)	11 52 A.M.,	No P.M. tide.	(6.)	0 19 P.M.	No A.M. tide.
(7.)	1 15 A.M.,	1 36 P.M.			

AMPLITUDES.

	° ′		° ′		° ′		° ′
(1.)	Var. 5 45 E.	(2.)	9 47 W.	(3.)	10 1 E.	(4.)	13 28 W.
(5.)	16 45 W.	(6.)	22 6 W.	(7.)	10 22 E.	(8.)	23 54 E.

CHRONOMETER.

		d h m s		° ′ ″
(1.)	T. G. M. T.	24 16 33 3,	Long.	69 36 0 E.
(2.)	T. G. M. T.	28 11 42 5,	Long.	122 25 0 W.
(3.)	T. G. M. T.	8 22 41 0,	Long.	87 49 30 E.
(4.)	T. G. M. T.	13 15 54 38.	Long.	178 2 15 E.
(5.)	T. G. M. T.	23 8 56 0,	Long.	178 59 30 W.
(6.)	T. G. M. T.	23 2 13 32,	Long.	34 33 15 E.
(7.)	T. G. M. T.	25 3 32 43,	Long.	134 50 15 W.
(8.)	T. G. M. T.	21 20 24 11,	Long.	0 31 15 W.
(9.)	T. G. M. T.	13 22 53 41,	Long.	70 22 0 E.

AZIMUTHS.

	° ′		° ′		° ′		° ′
(1.)	Var. 12 6 E.	(2.)	17 45 E.	(3.)	14 20 W.	(4.)	23 25 W.
(5.)	20 25 W.	(6.)	12 22 E.	(7.)	11 9 E.	(8.)	9 40 E.
(9.)	11 24 W.	(10.)	11 4 W.				

REDUCTION TO THE MERIDIAN.

		m sec		d h m sec		° ′
(1.)	H. A.	34 58,	A. G. T.	2 7 52 2,	Lat.	41 45 N.
(5.)	H. A.	17 37,	A. G. T.	6 5 22 23,	Lat.	51 11 S.
(3.)	H. A.	28 38,	A. G. T.	27 19 26 35,	Lat.	27 32 S.
(4.)	H. A.	16 58,	A. G. T.	3 10 48 2,	Lat.	26 10 S.
(5.)	H. A.	14 21,	A. G. T.	24 1 6 39,	Lat.	53 41 N.
(6.)	H. A.	32 25,	A. G. T.	11 14 32 25,	Lat.	37 49 N.
(7.)	H. A.	13 45,	A. G. T.	29 11 3 45,	Lat.	28 15 N.
(8.)	H. A.	50 18,	A. G. T.	9 22 41 18,	Lat.	60 18 N.
(9.)	H. A.	32 50,	A. G. T.	23 0 50 50,	Lat.	42 14 N.

MERIDIAN ALTS. OF STARS.

	° ′ ″		° ′ ″		° ′ ″
(1.)	Lat. 27 58 27 N.	(2.)	25 3 19 S.	(3.)	23 56 32 S.
(4.)	45 39 26 N.	(5.)	49 6 20 N.	(6.)	28 17 59 S.

DEVIATION (Corrected Courses.)

	° ′		° ′		° ′
(1.)	N. 27 32 W.	(2.)	S. 11 56 E.	(3.)	S. 60 42 W.
(4.)	N. 38 59 E.	(5.)	S. 87 6 W.	(6.)	N. 84 20 E.
(7.)	S. 48 35 W.	(8.)	N. 0 22 W.	(9.)	S. 84 7 W.
(10.)	S. 0 16 W.	(11.)	N. 9 40 E.	(12.)	S. 66 13 E.

ERRATA.

Page 23, Ex. 4, I. E. + 2′ 50″
... 24, Ex. 3, Dist. 650.7 miles.
... 25, *for* appointed *read* apparent
... 27, Ex. 2, Ans. $8^h\ 19^m$ — $7^h\ 54^m$
... 37, Ex. 2, Long. 122° 24′ W.
... 38, Ex. 6, Time by Chron. $23^d\ 3^h\ 37^m\ 26^{sec.}$
... 38, Ex. 7, slow, Oct. 12th.
... 43, Ex. 2, Lat. 13° 50′
... 45, Sun's $dec^{n.}$ 22° 26′
... 47, Ex. 3, H A $28^m\ 35_{sec.}$